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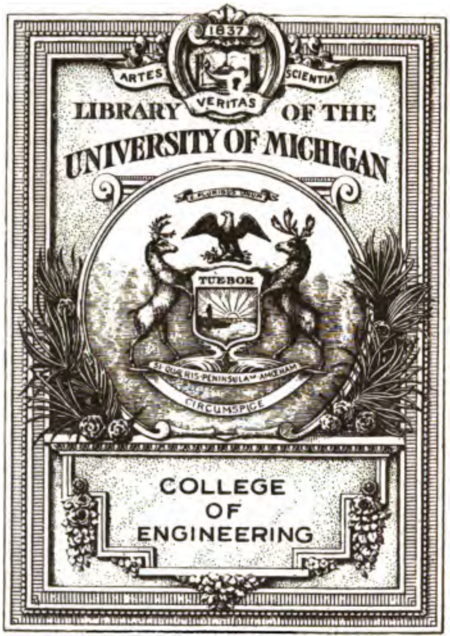

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# PRACTICAL HANDBOOK FOR BEET-SUGAR CHEMISTS.

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# Practical Handbook For Beet-Sugar Chemists

Rapid Methods of Technico-Chemical Analyses of the Products
and By-Products and of Material Used in the
Manufacture of Beet Sugar

BY

WERNER MOELLER-KRAUSE
Sugar Chemist

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# PREFACE.

The author does not claim of this handbook to contain heretofore unknown theories and methods, but has endeavored to condense the selected practical information obtained from standard works and other sources, to a small, convenient form.

It is evident that the manufacturing process, the chemistry of the various sugars and the polariscope could not be discussed exhaustively within the limits of a mere handbook, but the short outlines given will doubtless prove profitable to beginners.

The author takes this opportunity to thank Mr. Geo. M. Bradford for the complete revision of the manuscript, also Messrs. Eimer & Amend of New York for the loan of some of their electrotypes.

WERNER MOELLER-KRAUSE.

Bay City, Mich., 1914.

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# CHAPTER I.

# SUGARS.

## DEFINITION.

The production of sugar from cane seems to have been common in India and China in very remote times. It is also mentioned in the scriptures; the plant referred to, however, is doubtful.

Until the year 1747, sugar was only obtained from cane, when Margraf, a German chemist, demonstrated the existence of about 6 per cent. of sucrose in the sugar beet. Forty-eight years later, sugar was being manufactured on a farm in Silesia and loaves of the refined product were presented to William III of Prussia.

Chemically, the word "sugar" is applied to a large number of organic bodies belonging to the group of carbohydrates. These carbohydrates are divided into two groups with the composition $C_n(H_2O)_n$ and $C_n(H_2O)_{n-1}$ respectively. The first group includes dextrose (glucose) levulose and others, while sucrose (cane and beet sugar) belongs to the second group.

The sugars of the group $C_n(H_2O)_{n-1}$ undergo "inversion" on being treated with acids; that is, they take up hydrogen and oxygen in the same proportion in which these two elements unite to form water, and are converted into equal quantities of two of the sugars belonging to group $C_n(H_2O)_n$.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O = \underbrace{\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}}_{\text{Invert-sugar}}.$$

one of these always being glucose.

This process of inversion is also frequently termed "hydrolization."

The carbohydrates with reference to the number of carbon atoms they contain, are further divisible into three principal groups: The monosaccharoses, with six carbon atoms $C_6H_{12}O_6$; the disaccharoses, with twelve carbon atoms $C_{12}H_{22}O_{11}$; and the polysaccharoses, with a larger multiple of six carbon atoms $(C_6H_{10}O_5)_n$.

To the first two groups belong the sweet, crystalline bodies—the sugars; the third group constitutes the tasteless, amorphous bodies—the gums, starch, cellulose, etc.

The most important member of the group of disaccharoses is "saccharose" or "sucrose," commonly known as *cane* or *beet sugar*.

### SACCHAROSE OR SUCROSE.

Sucrose is not only found in sugar cane or beets, but is widely distributed in nature occurring in sorghum, palms, sugar maple, almonds; in honey and in the blossoms of many plants.

Up to the present time the main sources of production are the sugar cane and the sugar beet.

Sucrose crystallizes from water in large well-formed prisms which are anhydrous and unalterable in the air. It is insoluble in ether and in cold, absolute alcohol. Ordinary alcohol owing to the presence of water will dissolve more.

Sucrose does not reduce alkaline copper solution (Fehling's Solution). On being treated with dilute acids, sucrose is converted into a mixture of equal parts of two isomeric sugars (glucose and fructose). The mixture is known as *"invert sugar,"* and the process as *"inversion"* on account of the change of rotation when polarized, from dextrorotary to levorotary.[1]

---

[1] The power of changing the plane of polarization is characteristic of a large number of substances, the sugars possessing this property in a very marked degree.

If certain crystalline minerals, for instance tourmaline, are cut into thin plates parallel to the axis of the original crystal and two of these plates are placed together with their axes running in the same direction, light will pass through both very readily and they will appear transparent.

If now, one of these plates is rotated on the other, the part where they cross each other will begin to grow less transparent and as the point where the axes of the plates are at right angles to each other is reached, no light will penetrate the plates and they will appear opaque.

If the rotation is continued the light will gradually begin to pass through again and the crystals will again appear quite transparent when a position 180° from the initial position is reached.

The light passing through the first plate is called "*plane polarized*," a

(*Continued on page 3.*)

Saccharose resists the action of the alkalies and bases better than glucose forming with them compounds, called *"saccharates"* (see Analysis of Saccharates).

Sucrose itself is not fermentable, but is always subjected to the process of inversion before fermentation can take place.

Strong sulphuric acid decomposes and chars sucrose; strong nitric acid oxidizes it, forming oxalic acid.

At 10° C. water is able to dissolve 66 per cent. of sucrose; at 40° C. 76 per cent. and at 50° C., 83 per cent., a slight contraction in volume taking place at the same time.

Sucrose in the shape of crystals does not affect the polarized light, but as mentioned before it is dextrorotary in solution. Its specific rotation[2] is $[\alpha]_D^{20} = +66.5°$.

---

(*Continued from page 2.*)

peculiar condition caused by the rays of light passing through certain minerals as in this case, tourmaline.

The vibrations of light pass through the first plate parallel to its axis, and meeting the second plate the axis of which runs in a different direction, they are partly absorbed and if they meet the axis at a right angle they are completely absorbed. The first plate through which the light passes is called the "polarizer" and the one that is held next the eye (during observation) the "analyzer."

In actual practice, "Nicol prisms" are generally used instead of the mentioned crystal-sections.

If the analyzer is set in such a position that the polarized light is completely absorbed, that is, when the "field of vision" appears darkest, and a cylinder containing a solution of sucrose, and closed at each end by a disk of glass, is placed between analyzer and polarizer a partial restoration of light will be noticed. The angle of rotation varies with the strength of the sugar solution and with the length of the cylinder, and from the magnitude of the angle through which the analyzer has to be turned to appear opaque again, the power of the solution of turning the plane of polarization to the left or right is calculated.

Solutions of sugar rotating the plane of polarization to the right are called "*dextrorotary*" and those turning it to the left "*levorotary.*"

[2] "*Specific rotation*" is the deviation (a) of the polarized light caused by a solution containing one gram of substance in one cubic centimeter of liquid, polarized in a tube 10 centimeters in length, at 20° C. (20) using a sodium light (D) for observation.

## GLUCOSE.

Glucose or grape-sugar $C_6H_{12}O_6$ is found in honey, raisins and numerous other fruits and crystallizes from concentrated solutions at ordinary temperature in small rounded masses with one molecule of water. The crystals remain unchanged in air, melt when heated on the waterbath at 86° C. and at 100° C. they lose their water of crystallization. From alcohol, the anhydrous compound separates, these crystals melting at 146° C.

Glucose is one-third as soluble as sucrose and in solutions of equal strength is about one-third as sweet.

Heated to 170° C. it loses the elements of water and is converted into a colorless mass called *"glucosan."*

Glucose is dextrorotary in aqueous solutions, its specific rotation being $[\alpha]_D + 53.5°$.

Fresh, cold prepared solutions of glucose show the property of *"birotation,"* that is, if polarized immediately, they show nearly twice their actual reading. The addition of 0.1 per cent. of ammonia readily removes this condition, while without the addition, the normal is reached only about seven hours after the preparation of the solution. Boiling has the same effect as ammonia.

A solution of glucose is fermentable; with yeast it starts alcoholic fermentation, alcohol and carbon dioxide being produced.

Strong nitric acid converts glucose the same as it does sucrose, into oxalic acid.

Pure glucose dissolves in 1.2 parts of water. When lime or baryta solution is added to one of glucose, the "glucosates" of calcium and barium are precipitated. These compounds are soluble in water and are decomposed into sucrose and the carbonate of the respective metal by carbon dioxide.

Caustic alkalies added to a solution of glucose and heated, turn brown; an ammoniacal solution of silver nitrate is reduced by glucose and metallic silver is deposited. This reducing power is utilized in the quantitative determination of glucose and other sugars in the well known test with *"Fehling's solution"* (see Chapter VII).

### LEVULOSE.

Levulose, fructose or fruit-sugar $C_6H_{12}O_6$ is associated with glucose in many fruits and the mixture is most probably produced by the hydrolysis of cane sugar which is known to precede the formation of other carbohydrates in the plants.

To separate levulose from the invert sugar, the latter, in a quantity as obtained by inverting 10 grams of sucrose, is mixed with 6 grams of slaked lime and 100 cubic centimeters of water, when a solid "calcium fructosate" is formed, the glucose remaining in solution. The calcium fructosate suspended in water is decomposed by carbon dioxide and yields a solution of pure fruit sugar.

Levulose is, as the name implies, strongly levorotary, its specific rotation being $[\alpha]^{20}_{D} = -92°$.

Fructose is fermentable, though less readily than glucose; when a solution of invert sugar is fermented, glucose disappears first. Heated to 170° C. it loses one molecule of water, forming "levolosan," a dextrorotary compound.

Levulose is much sweeter than glucose and reduces alkaline copper solution (Fehling's solution).

### RAFFINOSE.

Raffinose or melitose, $C_{18}H_{32}O_{16}5H_2O$ occurs in Australian manna, in sugar beets and in cotton seed.

Sugar beets may contain 0.02 per cent. raffinose and being more easily soluble in water than sucrose, it is not removed during the purification of the juices and accumulates in the molasses during the manufacturing process. In the recovery of sugar from these molasses (Strontia, Steffen's, etc.), part of the accumulated raffinose is returned into the system of manufacture and thus gives rise to the peculiar, pointed, flat or needle-shaped crystals of granulated sugar.

Raffinose is insoluble in absolute alcohol, very soluble in hot water and in absolute methyl alcohol. Fehling's solution is not reduced by raffinose. The specific rotation of raffinose is $[\alpha]_D = +104°$, showing it to be extremely dextrorotary.

Raffinose crystallizes from aqueous solutions in long needle-shaped, white crystals, which, when heated to 100° C. lose their water (5 molecules). By hydrolysis, raffinose splits into glucose, fructose and galactose, the latter being a monosaccharose obtained from milk-sugar. (See Chapter VII for raffinose determinations).

### INVERT SUGAR.

Dilute sulphuric acid hydrolizes sucrose and converts it into equal portions of glucose and fructose. The levorotation of fructose more than neutralizes the dextrorotation of glucose, consequently invert sugar is levorotary.

Invert sugar is found in a large number of fruits and parts of plants. It is a sweet, colorless sirup, depositing crystals of glucose if exposed to light for a considerable time. It is easily soluble in water and dilute alcohol and shows the properties of its components, *viz.*, glucose and fructose in a marked degree. Invert sugar reduces Fehling's solution, this fact serving as a means of determining quantitatively the invert sugar in a mixture of it with sucrose.

The levorotation of invert sugar decreases with rise in temperature until at 88° C. it is zero and at a still higher temperature it changes to dextro.

The addition of lime, alcohol or lead acetate to an aqueous solution of invert sugar also causes a decrease of its levorotation, while compounds of sulphuric acid and chlorine with the alkalies increase the rotation.

The various methods for the determination of invert sugar will be found in Chapter VII.

# CHAPTER II.

## THE POLARISCOPE.

Referring to what has been mentioned in the preceding chapter regarding the property of sugar solutions of rotating the plane of polarization, it will be understood that this peculiarity furnishes a valuable means for the estimation of sugars in solutions. As the magnitude of the rotation increases in proportion to the strength of the solution, the percentage of sugar a solution contains can be calculated. The instrument designed for this purpose is called *"polariscope" "polarimeter"* or *"saccharimeter."*

These instruments consist essentially of the following parts: A nicol prism for polarizing the light; a tube of standard length to contain the solution under examination; another "nicol" movable on its axis for the adjustment to the deviation of the polarized light and finally a graduated arc to measure this angle.

Instead of having the nicol movable, a large number of polariscopes have an adjusting wedge of quartz of opposite rotative power to sucrose and the displacement produced on the polarized plane is hereby corrected. The movement of the wedge is measured and on a graduated scale, under certain conditions, the percentage of sugar is found directly.

Three types of polariscopes are in general use:

Instruments in which the magnitude of deviation is measured by rotating the analyzer about its axis. (Laurent, Landolt-Lippich).

Instruments with stationary Nicols, in which the deviation is determined by a wedge of quartz (Soleil, Duboscq, Schmidt & Haensch).

Instruments with the analyzer fixed in a certain angle with the polarizer. By varying the concentration or length of the interposed polarizing light, the compensation is secured (Trannin).

### FIELD OF VISION.

With reference to the appearance of their field of vision, polariscopes are classified as follows:

*"Shadow instruments"* with a field of vision of two semi-disks, one light and one dark colored, except when in the neutral or zero position where they appear to be equally colored. Fig. 1 illustrates the field of vision of the most used polariscope, the "half shadow" instrument.

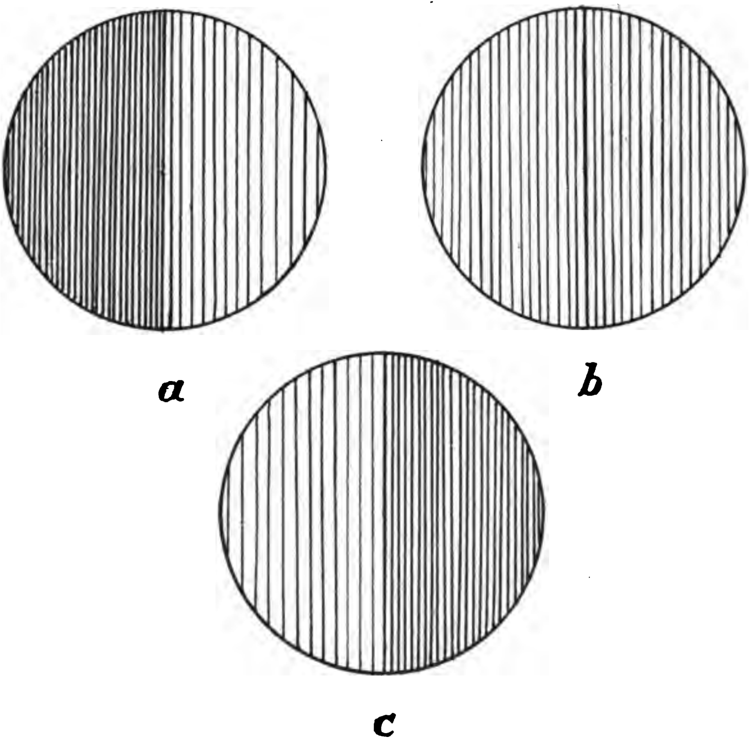

Fig. 1.

*"Tint instruments,"* in which the field of vision is also composed of two semi-disks of different colors (blue and red) in every position of the nicols, except in the neutral position where both appear evenly pink.

*"Striated instruments"* with the field of vision striated are also in use. Either by the disappearance of these lines or by their

meeting in the center (becoming continuous), the neutral position is indicated.

The light used for polariscopes differs with their construction. Some require "monochromatic light" (sodium flame) while others can be operated with common white light.

### THE LAURENT POLARISCOPE.

has the second nicol prism movable and the degree of rotation is read in angular terms from a divided circle graduated in per cent. sugar for a definite degree of concentration and a definite length of observation tube.

A Bunsen burner with some fused sodium chloride held in its flame by a small spoon-shaped platinum wire is required for this instrument.

The polarizer is a special nicol so arranged that it turns about its own axis. By this device, the quantity of light can be regulated making this instrument very useful with dark colored solutions for observation. However, the more light is admitted the less delicate is the reading.

In the Laurent polariscope the plane of polarized light falls on a disk of glass, half-covered with a semi-disk of quartz (Laurent plate) this part dividing the field of vision in halves. According to the position of the analyzer, which is also movable about its axis and which carries a graduated circle, the field of vision may be half-dark or both halves equally dark or illuminated. When by rotating the analyzer, the two halves appear uniform, that is, when both are equally illuminated the scale should read zero. The slightest rotation to the left or right will destroy this effect.

The normal observation tube for the Laurent instruments is 200 millimeters in length and every degree read on the scale with this tube, then corresponds to 0.1629 gram of sucrose in 100 cubic centimeters of solution. Consequently, if 16.29 grams of sugar or of a sugar solution are dissolved or diluted to 100 centimeters liquid and observed in a 200 millimeters tube, the percentage of sucrose in the solution will be shown directly.

## THE HALF-SHADOW POLARISCOPE WITH WEDGE COMPENSATION AND VENTZKE SCALE.

is now mostly used in sugar-laboratories in this country and a description will be given here. The "single wedge" is still in use but the improved forms of instruments have a double wedge compensation with two wedges of opposite rotative power. By their mutual correction a very accurate reading may be obtained.

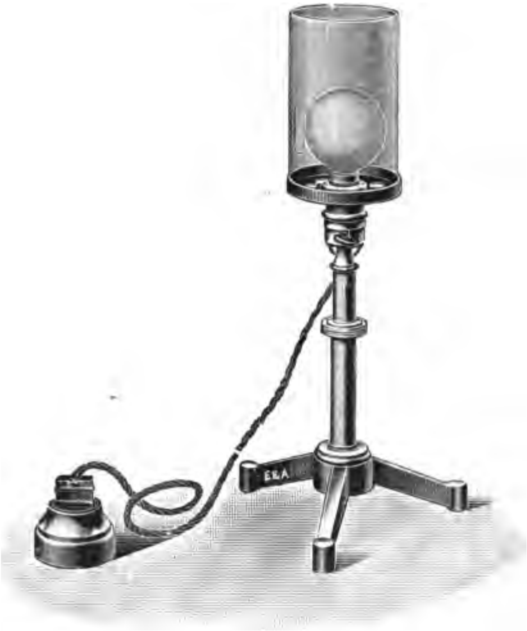

Fig. 2.

The optical parts of these instruments are arranged in the following manner. The rays of light from an oil lamp or electric light (round frosted-bulb tungsten, see Fig. 2) pass through a convex lens on the polariscope and meet the "half-shadow prism" (the distinguishing feature of this instrument) often called "twin nicol" consisting of two prisms placed together. This part serves as a polarizer and by its peculiar construction also divides the "field of vision" into two halves. The rays of light then enter the observation tube placed in its receptacle in the middle of the instrument and upon emerging from this tube, enter the "analyzing" part of the polariscope. This part consists of a quartz plate, the double or single wedge compensation carrying the scale, the analyzing nicol prism and finally the telescope, the latter adjustable to the eye of the observer to obtain a clear field of vision.

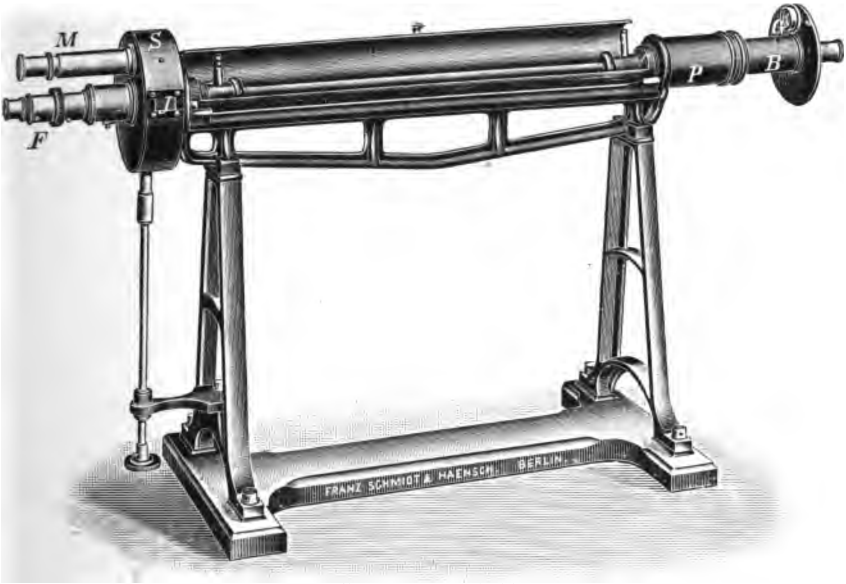

Fig. 3.

The scale is read by means of another small adjustable telescope provided with a mirror which is inclined at an angle of 45° over the scale to illuminate the latter.

The entire instrument is mounted on a strong tripod and in general practice is placed in a dark room or in a box painted black inside. The exclusion of outside rays of light greatly facilitates the reading and observation and for the same purpose, a large disk with a circular hole cut through its center is often placed between observation lamp and polariscope. An abestos-lined tin cylinder provided with a "bull's eye" adjusted in front of the polariscope is also frequently used to prevent unnecessary light from entering the observation room or box.

Care should be taken not to have the source of light too close to the front part of the instrument as the heat generated by the light is destructive to the material with which the optical parts are held in place and also otherwise affects their optical activity.

The normal weight for the half-shadow instrument with wedge compensation and Ventzke scale is 26.048 grams. Consequently one degree of this scale corresponds to 0.26048 of sucrose in 100 cubic centimeters of solution at 17½° C. if polarized in a 200 millimeter tube.

26.048 *grams of sucrose dissolved in water to* 100 *cubic centimeters of solution at* 17½° *C. (Mohr's cubic centimeters)*[1] *determines the* 100$^b$ *point of the Ventzke scale.*

The normal temperature of 17½° C. does not only apply to the graduation of the flasks, etc., but the temperature of the wedge compensation and consequently of the entire laboratory should be as near 17½° C. as possible.

Still another polariscope, the *Soleil-Ventzke* instrument, which is considerably used, deserves mention. The field of vision, here also consisting of two semi-disks, does not show different "shades" of color but in the neutral and zero position, appears evenly pink and when a sucrose solution is interposed, one semi-disk appears red and the other blue.

---

[1] The metric (real) cubic centimeter is the volume of one gram of water at a temperature of +4° C., its highest density.

Owing to the difficulty of working with such a low temperature, Mohr has established a cubic centimeter (*Mohr's cubic centimeter*) based on a temperature of 17½° C.

*Consequently, one Mohr's cubic centimeter is the volume of one gram of water at 17½° C. weighed in air with brass weights.* This is now the unit of volume generally adopted in this country for all sugar tests. Accordingly, all the flasks, etc., must be graduated in Mohr's cubic centimeters, this fact being assumed throughout this book as far as sugar analyses are concerned. (The new "normal" used in Germany is 26,000 grams of sucrose to 100 real cubic centimeters at 20° C.)

Any kind of light can be used with this polariscope which is very accurate and sensitive but only persons with a fine perception of color can obtain accurate results, therefore for technical purposes the common half-shadow Ventzke scale polariscope is always preferable.

# CHAPTER III.

## SHORT OUTLINE OF THE MANUFACTURE OF SUGAR AND OF THE METHODS TO DESUGARIZE MOLASSES.

This chapter is intended to give the beginner a general idea of the working of a beet sugar factory and of the various stages of manufacture and will enable him to better understand the chapters devoted to the analytical methods.

In the United States, the manufacture of beet sugar is but a young industry and through the efforts of men like Dr. Wiley, H. D. Oxnard, E. H. Dyer and others, has already grown to immense proportions.

In Europe, sugar has been manufactured from beets for about a century. The actual success of the industry however, has been assured since 1830 by the introduction of new, more economic methods and by careful selection of seed for beets, bearing as a necessary consequence a larger percentage of sugar in the beets.

The variety of beets to be used depends entirely upon the climatic and soil conditions of the country in which they are to be raised. The following are the most popular varieties (the names generally referring to the original grower or to the locality in Europe, where the seed is being produced):

Vilmorin Improved; Original Klein Wanzlebener; White Silesian; Dippe la plus Riche; White Imperial. All these varieties have given satisfaction throughout the United States.

The beets best adapted to the manufacture weigh between one and three pounds, very large as well as much smaller roots generally show a decrease in the percentage of sugar.

The seed is planted in rows between 18 and 20 inches apart to permit easy cultivation. The amount of seed required per acre varies greatly, from 18 to 21 pounds being taken as an average.

The time of maturity of the beets is determined partly by their appearance and partly by chemical analysis. When a percentage of sugar of from 14 to 20 and a coefficient of purity of from

81 to 86 is reached, the crop is ready to be pulled and sent to the factory.

### DETERMINATION OF THE "TARE" (SOIL ADHERING TO THE BEETS, BADLY TRIMMED NECKS, ETC.).

An accurate determination of the percentage of tare is essential in fixing the purchase price of a load of beets. In factories operating so-called "weigh-stations," the man in charge takes an average sample from every wagon load, the sample generally amounting to 20 pounds. The adhering dirt, etc., is then scraped off by means of a wire brush or the beets are washed in a suitable washing machine and the necks trimmed, removing all leaf scars if not done so already by the farmer.

The clean beets are then weighed again and from the loss of weight, the percentage of tare is calculated and recorded on the weight slip accompanying each sample. Some average beets are then taken from the sample, placed into a small bag together with the laboratory slip which also bears the name of the grower and his contract number, and this sample is shipped to the factory for a chemical analysis.

### WASHING THE BEETS.

The beets stored in the sheds of the factory are conveyed to the latter through cemented flumes, filled with running water. Raised by means of a large elevator wheel they fall into one end of the *"washer"* where they are agitated in contact with warm water, renewed at intervals, until thoroughly freed from dirt and finally, by a certain arrangement of the agitating arms, the clean beets are thrown out of the other end of the washer.

The beets are then, by means of a small conveyer or chute removed to the large beet elevator, which raises them to the third or fourth floor of the building where they are dropped into the *automatic scale*. These scales automatically weigh, register and dump their contents as soon as the large bucket is filled.

Different makes of scales are in use in this country, the "Libra" and "Chronos" being the most popular ones. They are made in different sizes, their capacity ranging from 500 to 2,500 tons in 24 hours.

## SLICING.

From the bucket of the automatic scale the beets fall into the *"slicer,"* a large cylindrical machine, where by a set of quickly revolving Y shaped knives they are cut into long V shaped slices (cossettes) about ⅛-inch thick. The object of this is to obtain as much acting surface as possible for the subsequent extraction of the sugar from the cossettes in the *diffusion* process.

## SAMPLING OF COSSETTES FOR THE LABORATORY.

The amount of sugar entering the factory is calculated from the percentage of sugar in the cossettes and from the amount of beets sliced; it is evident that the sample should be of good average and frequent sampling by taking a handful of cossettes at regular intervals and collecting them in a tightly covered pail is essential.

## THE DIFFUSION.

The next step is to remove as much sugar as possible from the cossettes by the process taking place in the *"diffusion battery"* where the following principle of diffusion is most successfully employed.

In the beet, the sugar is held in solution in its cells and while cold water would have no or little effect, upon heating, the sugar will begin to "diffuse" through the lining of these beet-cells and will continue to do so until the surrounding water will contain the same percentage of sugar as the juice inside of the cell. To make this better understood we will assume the example that the beet cells contain 15 per cent. sugar. By bringing these cells in contact with hot water, the sugar will diffuse through their lining until equilibrium is attained, that is, until 7½ per cent. of the sugar is in the water outside and the remaining 7½ per cent. is kept back.

Supposing this water is drawn off and some more hot water introduced, another half of the remaining 7½ per cent. sugar will diffuse, the water outside and also the cells now containing only 3¾ per cent. sugar. It is evident that by repeating this operation, the entire sugar contents of the beet can be extracted.

As mentioned before, this property of the beet cells is in actual practice utilized by means of a *"diffusion battery."*

A detailed description of the latter cannot be given here but the following explanation will give a general idea of the working of such a battery.

The diffusion battery generally consists of from 10 to 14 diffusors, also called "diffusion cells." They are large, round, upright iron cylinders, each holding several tons of cossettes, introduced through large manholes on top, which are then closed hermetically. To each diffusor, a heater or injector is connected which keeps the contents at the required temperature. The entire battery works under a pressure of from 15 to 25 pounds per square inch—generally water pressure.

The different cells are connected by means of pipes for water and juice in such a way that the same portion of juice can be drawn through the entire battery.

After the cossettes are exhausted, the resulting "pulp" is dumped through a large trap door at the bottom of each cell.

Now, we will again suppose that the beets contain 15 per cent. sugar and that the entire battery is empty.

Ten to twelve cells (depending upon their number in the battery) are packed full of cossettes and water heated to the required temperature is forced into cell No. 1. A certain amount of time having elapsed, the valve between cell No. 1 and cell No. 2 is opened and a fresh supply of hot water is drawn into cell No. 1 containing cossettes with only 7½ per cent. sugar. The valve to cell No. 2 being open, the previously introduced water of cell No. 1 now containing the other 7½ per cent. sugar is forced into cell No. 2, still containing the fresh cossettes. Here half of the difference between 7½ per cent. (sugar in the introduced juice from cell No. 1) and 15 per cent. (sugar in the fresh cossettes) again diffuses through the beet cells and at the end of this diffusion, cell No. 2 now contains cossettes with 11¼ per cent. sugar and also juice with 11¼ sugar. While this diffusion has taken place, the fresh supply of hot water that replaced the juice in cell No. 1 has also acted upon the cossettes left here with

7½ per cent. sugar and one half of this again will now be in the surrounding water.

Supposed the valves from No. 1 to No. 2 and from No. 2 to No. 3 are now opened and another fresh supply of hot water is drawn into cell No. 1. This forces the juice from cell No. 2 (11¼ per cent.) to cell No. 3 and the juice from cell No. 1 (3¾ per cent.) to cell No. 2, diffusion again taking place as the required temperature is kept up.

This process is carried on until from ½ to ¼ per cent. sugar remains in the cossettes, when the cell is dumped and refilled with fresh cossettes.

### SAMPLING OF EXHAUSTED COSSETTES FOR THE LABORATORY.

The sampling of the pulp is very important as the amount of sugar lost during the diffusion is thus established and controlled. A sample should be taken from every cell dumped and should be preserved in a tightly covered pail provided with a wire screen about two inches from the bottom and below which the water dripping from the pulp (waste water) is collected. The percentage of sugar in the pulp and waste water should be determined at least once an hour.

### DIFFUSION JUICE.

*Measuring the juice.*—The juice having by diffusion finally attained a high percentage of sugar, is then drawn from the battery in definite quantities depending on the quantity of beets worked and on the density it is supposed to have.

The measuring of the juice is effected in a so-called *"measuring tank."* The exact capacity of this tank is known and a large graduated scale automatically shows or registers the amount of juice drawn in. The measurement of the juice requires great care; a constant record is kept by marking down the time, the number of tanks filled the number of hectoliters drawn, the density and temperature of the hot juice and finally the number of cells filled in the battery.

### THE SAMPLING OF DIFFUSION JUICE FOR THE LABORATORY.

A half-gallon bottle should be kept near the measuring tank to collect the small definite samples taken from every tank. It is well to add a very small amount of *mercuric bichloride* or *thymol* to the juice in the bottle to prevent deterioration.

The analysis and correct sampling of the diffusion juice is very important as from the quantity, density and sugar content of this juice, the total amount of sugar entering the process of manufacture can be calculated. The amount of sugar found in the cossettes should, after deducting the losses in the battery, coincide with the above results.

### CALORIZATION BEFORE CARBONATION.

Before entering the process of carbonation, the juice is pumped or flows by gravity into a so-called *"calorisator"* where it is heated to 85° C. and by thus coagulating the albuminous matter which would otherwise cause trouble throughout the entire process, the juice is greatly improved and is now ready for the carbonation.

An analysis of the juice after passing the calorisator is generally not required.

### THE FIRST CARBONATION.

Before the juice is ready to be evaporated (boiled-down, concentrated) it is necessary to subject it to various methods of purification.

The first carbonation consists of large square tanks, the juice inside being heated by enclosed steam (coils), in order to avoid dilution. The tank having been filled with juice, the required quantity of *milk of lime* is added, the mixture heated and the resulting precipitate of calcium monosaccharate is then decomposed again by treatment with carbon dioxide gas ("carbonated"). Here, the sugar at first thrown down by the lime is set free again while most of the impurities of the juice remain in the precipitate.

The carbon dioxide gas is produced for this purpose by burning a mixture of limestone and coke in a so-called *lime-kiln*. The resulting gas should contain about 30 per cent. $CO_2$. It is blown into the juice by means of perforated pipes at the bottoms of the carbonation tanks until a test with standard acid shows about 1.0 to 1.5 grams of CaO per liter and a uniform, granular precipitate is formed.

The juice with the suspended precipitate is now forced through filter presses, where the precipitate is retained and the clear, light-colored juice runs out of the press. When the latter is filled with the precipitate, water is forced through and washes out most of the sugar contained in this *"limecake."* The small amount of sugar retained (about 1-2 per cent.), is calculated as loss and consequently an analysis is required.

### SAMPLING LIMECAKE FOR THE LABORATORY.

A good average sample should be taken from the press, care being taken that the hands are absolutely clean, as any sugar or juice adhering to them may cause a high percentage of sugar to be found by analysis and will thus lead to erroneous results in the calculation of the "losses." A sample of "thin juice" running from the presses is also taken and analyzed for density, sugar, purity, alkalinity, etc.

### THE SECOND CARBONATION.

After the filtration, the juice is once more treated with lime and $CO_2$ in another set of tanks similar to those of the "first carbonation." In this second carbonation, the gas is admitted until an alkalinity of about 0.5 gram per liter is reached. The action of the gas is also watched by means of test papers prepared by dipping thin, white filter-paper sheets into an alcoholic solution of phenolphthalein and drying them. They are then cut into thin strips. A very light pink color of the paper indicates when the carbonization is complete. Regular tests for alkalinity with standard acid are also made here, the same as on the first carbonation. Some factories, by adding soda carbonate prefer to leave a slight alkalinity due to that chemical rather than to lime.

On the completion of the second carbonation, the juice is heated for 2 or 3 minutes and filtered through a similar set of presses as that used for the first carbonation juice.

The cake obtained from this juice is of white color and if properly washed should not contain more than 0.4 per cent. sugar if any at all. For taking samples, the same precautions as for the "first cake" are necessary. The analyses are the same as for the first cake and juice and should be made every 2 or 3 hours.

## SULPHURING THE JUICE.

The next step in the manufacture of sugar from the juice is called *"sulphitation."* It is usually done by forcing $SO_2$ gas into the juice. The gas is produced by burning sulphur in small ovens.

During the process of sulphuring a temperature of about 95° C. is kept up and $SO_2$ added until the alkalinity is reduced to 0.10 or 0.20 gram of CaO per liter. This is determined by frequent acid tests at the sulphur station, checked in the laboratory.

The purpose of the sulphitation is to decolorize the juice and to precipitate the remainder of the lime.

The juice which is now comparatively pure is still very dilute and after passing through a set of *"mechanical filters,"* is subjected to evaporation.

## THE EVAPORATION.

The juice is boiled down to *"thick juice"* in so-called *"evaporators."* Four such evaporators connected together are called a *"quadruple effect"* which is the one generally used in this country, though triple and multiple effects are also constructed.

The quadruple effect evaporator consists of four bodies or "effects." These have the shape of an inverted U and have a steam chamber and tubes. The upper chamber or dome is the vapor chamber which is, by means of a pipe 20 inches in diameter, connected with the next body. The vapor chamber of this evaporator is again connected with the steam chamber of the third effect and so forth

The lower part of each evaporator (as high as the steam tubes) is filled with thin juice. Steam is then introduced into the steam chamber of effect No. 1. This causes the juice in this effect to boil and the resulting vapors (100° C.) arising from the boiling juice pass through the aforementioned large pipe into steam chamber and tubes of effect No. 2. When the juice in this effect boils, the rising vapors having a temperature of about 88° C. pass into steam chamber of effect No. 3 here also causing the juice to boil. The resulting vapors from this effect, now having a temperature of only 76° C., finally boil the juice in the fourth effect.

In actual practice, when starting the set, live steam is introduced into effects No. 2, 3 and 4 as well, but as the required temperatures are reached, generally only No. 1 receives steam.

The difference in temperature of the boiling juices in the effects is caused by the difference in the vacuum which is maintained by means of a pump. The fourth effect is connected with this pump through a condenser. Thus the fourth effect having the highest vacuum and the lowest temperature, also acts as a condenser to the third; the third to the second and the second to the first effect.

The juice is here boiled down to a density of about 30° Baumé and is then called *"thick juice."* Samples of thick juice are frequently taken from the fourth effect and analyzed.

### CRYSTALLIZATION IN THE VACUUM PAN.

The *"vacuum pan"* is a cylindrical upright vessel with a semi-spherical top and bottom and holds about 35 or more tons of *massecuite* (*fillmass*) *i. e.,* sugar crystals with adhering molasses. The pan contains copper coils through which the steam for boiling the juice is passing. In order to prevent burning of the mass a high vacuum is constantly maintained in the pan, thus causing the very heavy mass to boil at a comparatively low temperature. A condenser connected with the pan condenses the rising vapors.

"To start the pan," the latter is filled about half full with thick juice, which is then boiled down until microscopic crystals of sugar begin to form (at about 43° Baumé). Fresh thick juice is now introduced, care being taken not to redissolve the crystals by adding too much juice. Upon further boiling, the sugar that was in solution in the last introduced portion of thick juice will deposit on and cause these small crystals to grow, without forming new ones. This drawing in and boiling down is continued until the pan is filled and the crystals have reached the required quality and quantity.

The work of "sugar boiling" requires considerable practice and must be watched very closely. Much depends upon the efficiency of the sugar boiler as a large amount of work and money is involved in every pan boiled.

The boiling being completed, the massecuite is dropped into the *"mixer,"* a long V shaped trough, where by a number of slowly revolving agitating arms, the mass is prevented from solidifying and is kept well mixed.

As soon as the "strike is dropped" as the manipulation of emptying the pan is termed, a sample for the laboratory is procured and the Brix, sugar, purity, alkalinity and hardness determined.

### "SPINNING" THE MASSECUITE.

The crystals of sugar still mixed with molasses (sirup) must be separated from the latter. This is most successfully accomplished by making use of the *law of centrifugal force.*

Situated directly under the mixer are a number of *centrifugals* consisting of quickly revolving (1,000-1,500 revolutions per minute) screen lined "baskets" surrounded by safety curbs.

Several hundred pounds of massecuite are taken into the centrifugal from a specially constructed tap in the bottom of the mixer above. The centrifugal being started, the force throws the mass against the screen where the sirup adhering to the sugar crystals will readily pass through while the latter are held back by the screen and remain inside.

The sirup now thrown out of the centrifugal is called *"green sirup"* and is collected in a special tank, from where it is later pumped into another vacuum pan and again boiled down to crystallization. This strike, called *"brown strike"* or *"second pan"* is then run into a so-called *"crystallizer."* Portions of the *"green* sirup" may also be taken into the "white pan;" the amount to be used in this manner will vary with the purity of the first massecuite.

Returning to the centrifugals; there is still some molasses adhering to the sugar and in order to remove this, a fine spray of water is directed against the crystals which now form an incrustation on the screen covering it evenly from top to bottom. The sirup produced during this washing is called *"wash sirup*. It is run into another tank and later pumped back into the "white pan."

By subsequent treatment with a blueing solution, the sugar is finally left in a perfectly white state. The centrifugal is now stopped and the sugar scraped off the screen falls through a trap-door in the bottom of the machine into a conveyer that removes it to an elevator from where it falls into large, slowly revolving drums, *the "granulators."*

The inside of these drums is heated by means of steam coils and the sugar is here thoroughly dried and screened to separate any lumps that may have formed; it is then ready to be packed and shipped.

## THE CRYSTALLIZERS.

As mentioned above, the green sirup is again boiled down to a "brown pan" which is dropped into a "crystallizer." Here, this "second massecuite" is kept in constant slow motion by means of agitating arms, until, as determined by analysis, all the crystallizable sugar of the molasses is crystallized.

The crystallizer is then "dropped," that is, the massecuite is by means of a conveyer run into the *brown sugar centrifugals* where the molasses is separated from the sugar and pumped into a large tank for further treatment. The brown sugar is melted and returned into the system by mixing it with the thick juice.

If, by analysis it is found that the molasses obtained from this brown sugar does not contain any more crystallizable sugar to have it profitably removed by the ordinary methods described above, it is subjected to one of the following processes for the recovery of the sugar.

## THE OSMOSE PROCESS.

It has been discovered that the "salts" contained in beet-molasses prevent a certain amount of sugar from crystallization in the proportion of one part of salts to 3.5 parts of sugar.

The molecules of these salts are smaller than those of sugar and consequently, if molasses is separated from water by a membrane of parchment paper, the molecules of the salts will diffuse (dialyze) through the pores of the paper more easily than those of the sugar. This law of *dialysis* is utilized in the osmose process.

The machines used for this purpose consist of a set of presses similar to those used for filtering carbonation juices except that the frames are made of wood, and parchment paper instead of cloth separates the compartments. The latter are filled alternately with molasses and water. Part of the salts contained in the molasses will then dialyze through the parchment paper and some of the water will, in turn, enter the molasses and cause a dilution. This, however, is immaterial, as water does not decrease the purity of the final product. The organic non-sugar also present in the molasses will not pass into the water and diffusing even more slowly than sugar, prevents the whole of the sugar content to be recovered.

After osmosis, the "osmosed" molasses is boiled in the vacuum pan, held for a period of time in crystallizers or tanks and finally spun in the centrifugals. The molasses from this sugar can be treated again and if profitable, a third time.

Suppose a molasses containing 11 per cent. ash and 45 per cent. sugar is subjected to the osmose. As 1 per cent. of ash prevents 3.5 per cent. of sugar from crystallization, the molasses with this percentage of ash could not be profitably treated for sugar by concentration. After osmotic treatment, this molasses will contain about 5 per cent. ash and 38 per cent. sugar. This 5 per cent. ash will retain 17½ per cent. sugar and this deducted from 38 per cent. sugar contained in the molasses will show that now, another 20.5 per cent. sugar can be recovered.

Samples of molasses (entering and out-going) are frequently taken and analyzed. The same applies to the "osmose water." The density, sugar, purity and alkalinity are usually determined. The sugar contained in the osmose water is calculated as "loss" and a good average sample is necessary. The osmose process is now being largely replaced by the Steffen's process.

### THE STEFFENS PROCESS.

This process named after its inventor is employed with the greatest success in this country; it depends on the solubility of tri-calcium saccharate at low temperatures.

The final molasses pumped to the "Steffen's house" for treatment is diluted with water (wash water from the presses) down to about 11° Brix and the well agitated mixture run into the "cooler," a large round tank containing a cooling chamber through which a continuous supply of the coldest water obtainable is pumped. The molasses is continually forced through a number of tubes in this cooling chamber as it is very important to keep the temperature below 15° C.

The cooler being filled with the required amount of dilute molasses, a weighed quantity of finally powdered quicklime is sprayed over the liquid which, as mentioned before, is kept in constant motion in the cooling chamber. The proportion of lime and molasses to be mixed varies with the quality of both.

The lime first goes into solution but eventually separates again as tri-calcium sucrate. The work of the coolers is controlled by frequently examining the filtrate from the saccharte by means of a special Brix spindle, small enough to be used in a large test tube, so that only a small quantity of the rather slow-filtering solution is required. A record of the density, the length of time required, the weight of lime and molasses used and the temperature of every cooler is kept.

The treatment in the cooler being completed, the mixture is pumped into filter presses, similar to those used for the carbonation juices. Here the liquid (waste water) is separated from the precipitate (saccharate). The former contains the mineral matter of the molasses and about 0.50 per cent. sugar and is generally thrown away or, as recent experiments conducted by Mr. H. A. Vallez have shown; it may be evaporated (concentrated) and mixed with dried limecake from the carbonation presses, thus forming a valuable fertilizer.

When the press is filled with the saccharate, water is forced through and the "wash water" thus obtained is used to dilute the next portion of molasses for the cooler.

The final product of the Steffen's process is a saccharate with a high purity; it is successfully used in a dilute state in the carbonation of the raw beet juices. The purity of this *"saccharate milk"* is determined by analysis in intervals of about 3 hours. For this purpose, the laboratory should be equipped with a small carbonation tank and a small vacuum pan.

Waste water and cooler solution should be analyzed every hour.

Close resemblance to the Steffen's process bears the so-called *"elusion" process.* Various methods and modifications have been devised but all depend more or less on the following principles:

By means of an edge runner, the molasses is mixed with about 25 per cent. by weight of quicklime and the mixture kept cool by a cooling arrangement As soon as the mixture is complete it is transferred to small iron chambers where the temperature rises spontaneously to about 100° C. and tri-calcium saccharate $3\ CaO.C_{12}H_{22}O_{11}$ is formed with the expulsion of the surplus water and the formation of a hard mass.

This mass is broken up and extracted systematically in an apparatus resembling a diffusion battery, with 35 per cent. alcohol which dissolves the impurities and leaves the saccharate in a pure state. The extract is distilled and the alcohol thus recovered is used for another portion of saccharate while the alcohol left in the latter from the extraction is removed and recovered by steaming, which treatment also partly decomposes the tri-calcium saccharate yielding mono-calcium saccharate and lime.

This mono-saccharate is generally used for the carbonation process, where the acid of the beet juices is neutralized by the lime and liberates an equivalent quantity of sugar which is then worked up with the sugar of the juice.

## THE STRONTIA PROCESS.

The strotium hydrate required in this process is generally prepared at the factory by burning the mineral "strontianite" which is strontium carbonate, to strontia (strontium oxide). This is similar to the burning of lime except that a gas furnace is preferred in order not to have the rather expensive strontia contaminated with the silicious ash of solid fuel.

The principle of a recent modification of the strontia process by Scheibler, depends on the formation of mono-strontium saccharate when a solution containing about 25 per cent. sugar is treated with strontium hydrate at a temperature of about 70° C. The temperature must be kept above that at which the di-strontium saccharate forms and the strontium hydrate is added in slight excess.

A crystal of mono-strontium saccharate is then added to the liquid and the precipitate filtered off. The filtrate is boiled with strontium hydrate, when di-strontium saccharate which is used instead of the hydrate for the treatment of another portion of molasses (thus yielding another crop of mono-strontium saccharate) is precipitated.

The total quantity of mono-strontium saccharate is decomposed by dissolving it in water cooling and adding a crystal of strontium hydrate.

Mono-strontium saccharate is a very unstable compound. The addition of a crystal of strontium hydrate determines the precipitation of this hydrate and that of a crystal of mono-strontium saccharate throws the salt down.

The sugar is freed from the remaining strontia by carbon dioxide and the solution is then boiled down in the vacuum pan in the usual way, while the recovered strontium hydrate is reused during the process.

The filtrate obtained from the di-strontium saccharate yields strontium hydrate on crystallization and the residual strontia is recovered as carbonate. The final filtrate then contains the impurities from the molasses.

The strontium carbonate obtained as a by-product is taken from the filter presses, molded into bricks and burned in the same manner as the original strontianite. The strontia is then slaked (hydrated) the hot solution run off and allowed to crystallize when nearly the whole amount of the strontia is deposited as strontium hydrate, $Sr(OH)_2 8H_2O$.

## THE BURNING OF LIME IN THE KILN.

The lime and carbon dioxide gas employed in the manufacture of sugar, mainly for the purification of juices, is generally produced in the factory in so-called "lime-kilns."

These kilns are tall, truncated cones made of sheet iron and lined with fire-clay bricks. They are also provided with collecting flumes, through which the carbon dioxide gas is drawn off.

The process of burning is based on the following principle:

$$CaCO_3 = CaO + CO_2$$

The relative quantities of coke and limestone used in the burning process vary greatly and also depend on the quality of the stone. Theoretically, 6 pounds of coke are required to decompose 100 pounds of stone.

The space between the lower opening of the kiln and the floor is first filled with limestone rocks for a foundation and about two tons of wood and half a ton of coke added. The kiln is provided with an elevator which takes the materials up to the top from where it is fed.

The physical condition as well as the chemical composition of the stone play an important role in the working of the kiln. The stone should be compact and hard and should not contain excessive moisture (more than three per cent.) as this is liable to reduce the temperature of the kiln when charging, thus causing an imperfect combustion which leads to the formation of carbon monoxide. Furthermore the stone should not contain much silicate as this shows a tendency to fuse if overheated and part of it will later cause difficulties in the filter presses by coating the cloths. It may be said however, that a very hard stone containing much silica is admissible and will not cause these difficulties.

## THE REFINING OF RAW SUGAR.

Though this volume is intended for the chemist of the beet-sugar factory, a short outline of the refining process will not be out of place.

The process of refining is essentially the same for raw sugar of all sources, although the sugar varies considerably in composition, containing from 90 to 95 per cent. of sucrose, the balance consisting of mineral constituents, organic non-sugar, water and a very small amount of invert sugar.

The raw sugar is dissolved in water with the aid of steam to obtain a solution containing about 50 per cent. sugar and having a temperature of about 70° C. To very impure sugar, blood is added, the solution heated and the coagulation of the thus introduced albuminous matter effected.

The next step is the filtration of the solution in a so-called Taylor filter, consisting of a cast iron box covered with a perforated cover to which narrow bags of hemp containing the real filter bags made of cotton fabric are fastened. The opening of each bag is fastened to a nozzle in the perforations of the cover which at the same time forms the bottom of a shallow tank filled with the sugar solution. An even distribution and rapid filtration is thus effected.

After use, the bags are washed and the wash water is utilized to dissolve another portion of raw sugar, after it has been purified by lime and subsequent filtration.

After passing the Taylor filter, the warm, clear sugar solution is allowed to run through animal charcoal for the purpose of decolorization. Large iron towers provided with perforated false bottoms and filter cloth are packed full of charcoal; the solution is run on at the top and the decolorized liquid drawn off at the bottom. The sugar solution is then ready to be concentrated to grain in a vacuum pan and is subsequently centrifugated as described before.

It is evident that the charcoal, owing to its continuous absorption of coloring matter, impurities, etc., will in time become saturated, which is indicated by the yellow color of the liquid running off at the bottom of the tower.

As soon as this is observed, the supply of fresh liquid is stopped and water is substituted, which is afterwards again used to dissolve the raw sugar. When the absorbing power of the boneblack has been completely exhausted, it is made fit to use again by a process called "revivification."

This is first effected by thorough washing with water or hydrochloric acid in an amount sufficient to destroy the calcium salts taken up by the charcoal as determined and calculated by an analysis. The organic matter also absorbed, is subjected to a fermentative process, whereafter the products of this decomposition are easily removed by washing.

The charcoal is next submitted to a reburning process where it is heated out of contact with air to about 650° C. The revivified charcoal is then dropped out of the kiln, cooled in a set of pipes and finally retransferred to the towers.

A test is made after the reburning to determine whether the process has been properly conducted, by boiling a small quantity of the charcoal in a solution of sodium hydrate of about 5° Baumé, filtering into a test tube and observing its color.

A pefect revivification is indicated by a faint tinge of color while a greenish or colorless filtrate shows over-revivification. If on treating charcoal with sodium hydrate, a greenish color is obtained, it indicates calcium sulphide, which greatly effects the quality of the coal and if present in more than very small quantities, renders it entirely valueless.

The "increase in weight" of the boneblack serves as a measure to determine its deterioration from usage. The weight is determined per cubic foot and averages about 45 pounds for fresh material. This original weight is recorded and the increase in weight determined after a certain amount of usage.

A final increase of 50 per cent. in weight is assumed as the limit and renders the charcoal useless for further use. It is then utilized as a fertilizer.

# CHAPTER IV.

## THE ANALYSIS OF SUGAR BEETS.

**1. Introductory.**—The analysis of sugar beets forms so-to-speak the foundation for the different calculations used in the sugar factory. It gives us the amount of sugar entering the factory in the form of beets and by deducting the losses during the manufacture, we know how many pounds of white sugar should be manufactured from a certain quantity of beets.

The beets in their original state, however, are not fit for analysis but the fiber must be first brought into a fine state of division.

This is done best by rasping a cross-section (representing an average sample) of each beet of the sample sent for analysis, in a special machine generally consisting of a quickly revolving solid wooden cylinder from which a large number of spikes are protruding. Machines of different construction have been invented for this purpose but the above described is mostly used in this country and produces a sufficiently fine, homogeneous pulp.

Cossettes from the slicer, of course, cannot be rasped in this machine and are most conveniently passed through a medium size sausage grinder. In each case, the pulp, before being tested should be mixed well with the hands and should not be exposed to the air for a long time.

The following analysis gives the average composition of a sugar beet which, however, varies greatly according to the time of the year:

| | Per cent. |
|---|---|
| Sugar | 11.8 |
| Water | 82.4 |
| Cellulose | 0.7 |
| Caseine, albumen and fatty matter | 1.5 |

Organic substances and salts: *viz.*, betain, asparagin, asparic acid, pectin, pectic acid, the oxalates and pectates of potassium, sodium and calcium and also the following inorganic salts: calcium and magnesium phosphate and the nitrates and sulphates of potassium.—3.6 per cent.

A complete analysis like the above is seldom required in actual practice. The most frequent determinations made in a sugar factory are the percentage of sugar, the percentage of juice and of water contained in the beet, also the dry substance and very rarely the percentage of invert sugar.

**2. Determination of the Percentage of Sugar in the Beet.**—The various methods used for this determination can be divided into 2 groups, *viz*: the extraction by alcohol and the extraction by water. These again are subdivided into cold and hot methods. The former require a finally ground, homogeneous beet pulp, while for the latter, a roughly rasped pulp may be used with advantage.

A description of all the methods in use would be too lengthy and unnecessary. The methods described in the next pages are accurate and do not require much time.

**3. Pellet's Cold Diffusion.**—Referring to Chapter II, it has been mentioned that for the half-shadow polariscope with Ventzke's scale, now almost universally adopted in sugar laboratories, the normal weight of a substance to be examined for sugar is 26.048 grams, diluted to 100 cubic centimeters (Mohr's). This, of course, still holds good in all analysis described here. One-half or twice this normal weight may be taken and the polariscopic reading multiplied or divided by 2 as the case requires, and the final result will be just as correct.

In Pellet's popular method, the normal (26.048 grams) or twice the normal (52.096 grams) weight of the fine pulp obtained by rasping the cross sections of sample beets, is quickly weighed out in a nickel sugar dish (scoop) and by means of water washed into a sugar flask, graduated at 201.35 cubic centimeters. (The marc of the beet pulp amounts to about 4 per cent. and the volume of this is calculated and universally assumed to be 1.35 cubic centimeters. Consequently, flasks of this capacity are being manufactured especially for this purpose.) The neck of such a sugar flask is wider around the top to facilitate the introduction of the beet pulp, which is best done with the aid of a glass rod, care being taken to avoid any loss, no matter how small. Fig. 4 illustrates such a special sugar flask. In case a 201.35 cubic centimeter flask is not at hand, a 200 cubic centimeter flask may be used and only 25.870 grams instead of 26.048 grams of the pulp weighed out.

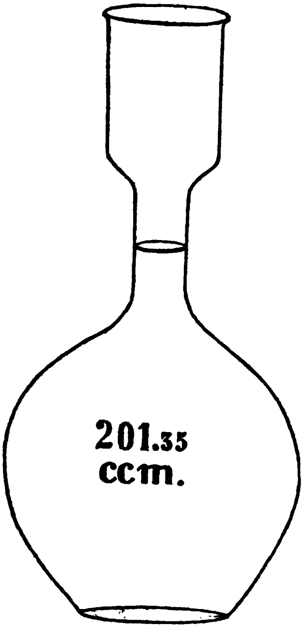

Fig. 4.

For the purpose of clarification, 6 cubic centimeters of subacetate of lead[1] having a specific gravity of about 30° Baumé are added to the pulp in the flask.

The flask which should now be about three-quarters full is then filled to the mark with water and the contents thoroughly mixed by closing the opening with the palm of the hand and shaking vigorously.

In case the pulp has been rasped fine enough, the contents can be filtered after a few minutes, otherwise the flask, after shaking, is allowed to stand for half an hour at ordinary room temperature (17½° C.).

It may be mentioned here that the water used to wash the pulp into the flask and also that to fill the latter up to the mark should also be of ordinary room temperature. When filling up to the mark (this applies to all sugar analyses) the center of the surface of the liquid should be carefully made even with the mark. Where the liquid touches the glass, as will be noticed, it rises owing to adhesion slightly higher and the surface thus form a curve, the bottom of which (lower meniscus) should be even with the mark on the flask. (See Fig. 5.)

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[1] It is always required, in all sugar analyses (except for white, refined sugar), to add a clarifying and decolorizing agent before polarization can take place, as a perfectly clear liquid is of great importance to secure accurate results in the polariscope.

A solution of *basic lead acetate* is almost exclusively used for this purpose. It precipitates the organic compounds contained in the solution and the precipitate formed at the same time helps to keep any suspended impurities back in the filter paper. (Preparation, see Chapter XV.)

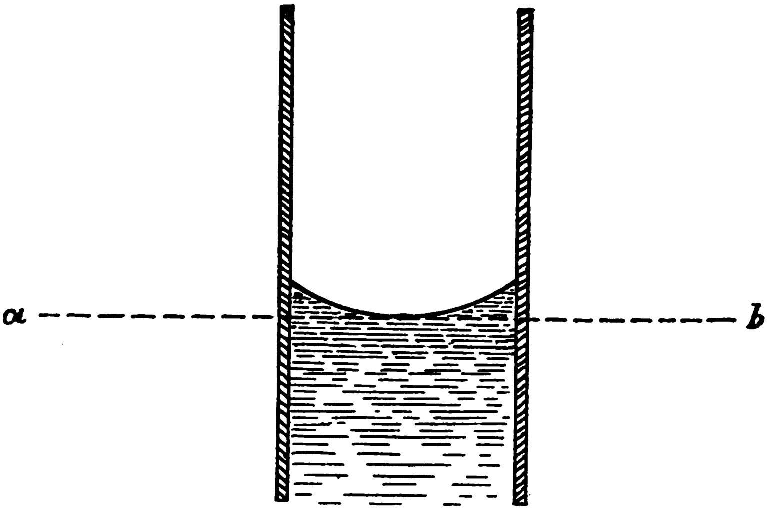

Fig. 5.

The solution should be filtered through paper in a glass funnel (large enough to hold the entire contents of the flask) into a beaker (Fig. 6). The first small portion filtering is generally rejected. When enough filtrate has been collected, the funnel is removed from the beaker and the observation tube,[1] preferably 200 millimeters long, after rinsing it out with some of the solution, is filled and the cover-glass screwed on. It is then ready for the polariscope.

Fig. 6.

The reading obtained will be the per cent. of sugar contained in the beets, provided 52.096 grams of pulp, a 201.35 cubic centimeter flask and a 200 millimeter tube have been used.

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[1] **Where a large number of observations have to be made, "Pellet's continuous tube" is used with advantage.**

If any foam, which makes it difficult to accurately fill the flask to the mark, is formed, it may be removed by the addition of two or three drops of *ether*. This applies to all sugar tests.

**4. Pellet's Hot Diffusion Method.**—Cossettes which have simply passed through a sausage grinder, and form a rather coarse pulp cannot be successfully extracted by a cold method like Pellet's cold diffusion and heat must be applied to the solution in the flask.

Proceed exactly as in the cold method, add 6 cubic centimeters of lead acetate and fill with water to the neck of the flask (about one and one-half inch below the mark). Then place the flask in a water bath previously heated to about 80° C. and keep at this temperature for 30 minutes, shaking the flask at intervals of about 5 minutes.

Take flask out of the water bath and cool to room temperature in cold water, throw foam down with ether, fill to the mark, shake, filter and polarize.

The hot water-bath should contain enough water to entirely cover that part of the flask which contains the sugar solution, so that the surface of this is below that of the surrounding water.

**5. Hot Digestion with Alcohol; Rapp and Degener's Method.**—This method depends on the extraction of the sugar by *alcohol*. Exactly 52.096 grams are weighed out and with the aid of a glass rod and 90 per cent. alcohol from a wash-bottle, washed into a sugar flask of 200 cubic centimeters capacity provided with a widened neck into which a glass tube about 18 inches long is subsequently fastened by means of a tight-fitting cork.

Particles of pulp adhering to the scoop and glass rod are also carefully washed into the flask with alcohol of the same strength.

The flask is now filled with alcohol to about four-fifths its capacity, the long glass tube which acts as a condenser is inserted and the whole arrangement placed in a water bath and heated to boiling for about 20 minutes.

The extraction being complete, the flask is removed from the water-bath, the condenser and cork rinsed with alcohol, and the flask filled with it to slightly below the mark. It is now again placed into the water-bath for about 2 minutes until bubbles begin to rise in the alcoholic solution after which it is allowed to cool for half an hour in the air and finally by immersing it in water of room temperature.

After the addition of 20 drops of lead acetate, the flask is filled to the mark with alcohol, the contents thoroughly shaken, filtered and polarized in a 200 millimeter tube. To allow for the volume of the extracted pulp (a 200 cubic centimeter flask having been used), the polariscope reading thus obtained is multiplied by 0.994.

The above method requires more time, but as to accuracy, it is to be preferred to the aqueous diffusion methods. A coarse pulp may be used.

**6. Determination of the Percentage of Juice in the Beet.**—This determination is sometimes required and a description will follow here.

The average percentage of the "marc" of the beet amounts to about 5 per cent., consequently the percentage of juice is generally about 95 per cent.

Twenty grams of the finely rasped pulp (the finer the better) are quickly weighed out in a scoop and, by means of water, washed into a large beaker without loss. About 400 cubic centimeters of cold water are then added and the mixture is allowed to stand for half an hour.

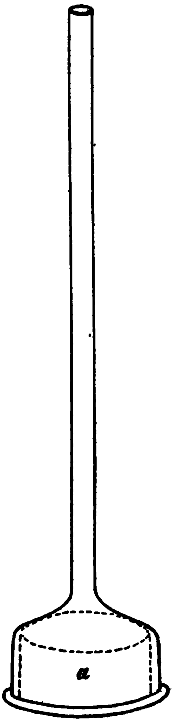

Fig. 7.

For the next step of the analysis, a so-called *"felt filter"* is required. It consists of a glass tube about 5 inches long, one end of which is widened into a cup-shaped receptacle into which a stopper of fine felt (a) fits tightly. (See Fig. 7.)

The other end of the tube is by means of a rubber tube, connected with a large bottle wherein the filtrate is collected. A vacuum is produced in this bottle by a suitable pump.

The felt filter is placed into the beaker and connections having been made, the juice is drawn up through the felt while the marc (fiber) of the beet will remain in the beaker. Another supply of water is then added to the residue in the beaker and after half an hour again drawn off into the bottle. This is repeated until no more soluble matter is given off by the remaining pulp.

Finally hot, distilled water is employed and with the aid of this, the residue is transferred to a previously dried and weighed paper-filter. Particles of pulp adhering to the felt filter and beaker are also carefully washed into the paper.

The water having filtered through, several portions of 90 per cent. alcohol are poured over the marc, in order to remove the last traces of soluble matter. A small quantity of ether finally removes the remaining alcohol and the residue should then be left entirely colorless. This, including the filter paper is now transferred to a watch glass and placed in a drying oven where it is dried to constant weight, at first at a low temperature and finally at a 110° C. (If the residue becomes sticky, it indicates that a trace of juice is still present, and it should therefore be treated once more with distilled water). This, however, should not be necessary if the above directions have been followed closely.

Example:

| | Grams |
|---|---|
| Watch glass, paper filter and residue................ | 28.871 |
| Watch glass and paper filter......................... | 28.002 |
| Residue ............................................. | 00.869 |

The constant weight having been obtained, the dried residue and filter paper are transferred to a platinum crucible and heated over a Bunsen burner to "complete incineration."

The remaining ash consisting of sand and similar matter, is weighed and the known weight of the ash of the filter paper deducted.

Example:

| | Grams |
|---|---|
| Platinum crucible and contents | 15.087 |
| Platinum crucible | 15.077 |
| Filter paper ash, and pulp ash | 00.010 |
| Filter paper ash | 00.005 |
| Ash of pulp (sand) | 00.005 |
| Residue, marc and sand | 00.869 |
| Sand | 00.005 |
| Marc | 00.864 |

If 20 grams of beet pulp contain 0.864 gram of marc, 100 grams will contain 4.32 grams or, in other words, the beet sample analyzed contains 95.68 per cent. juice.

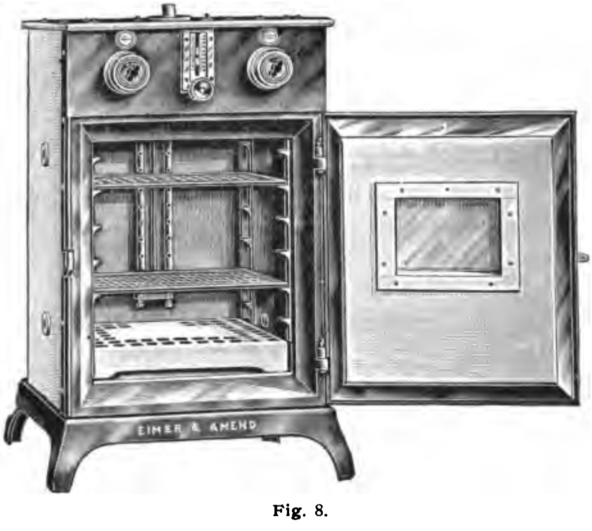

Fig. 8.

**7. Determination of the Percentage of Water in the Beet.**—Ten grams of finally rasped beet-pulp are quickly weighed out in a large watch glass and placed in a *drying-oven*[1] at 60°

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[1] Fig. 8 illustrates a modern type of drying oven. It is the *Freas* electric oven which has given great satisfaction for constant temperature requirements in sugar laboratories.

C., finally raised to 110° C., until *constant weight* is obtained. This is found by removing the watch glass containing the dried residue to a "desiccator" and after cooling, weighing it. It is then returned to the drying oven and after an hour, again cooled in the desiccator and weighed. If no loss in weight from the preceding weight has taken place, this may be taken as the "constant weight."

Example:

| | Grams |
|---|---|
| Watch glass and pulp after drying | 29.971 |
| Watch glass, empty | 27.985 |
| Dry substance | 1.986 |

Ten grams of beet pulp contain 1.986 grams of dry substance; 100 grams will contain 19.86 grams, consequently, the sample of beets contains 80.14 per cent. water.

(If an exceedingly fine pulp is to be tested for water, the determination must be made according to directions given in Chapter V, Art. 15.)

# CHAPTER V.

## THE ANALYSIS OF BEET AND THIN JUICES.

**8. Determination of the Specific Gravity and the degree Brix.**—*The "specific gravity" is the weight in grams of one cubic centimeter of a substance, or in other words, the specific gravity of a liquid or a solid is the ratio of its weight to the weight of the same volume of water.*

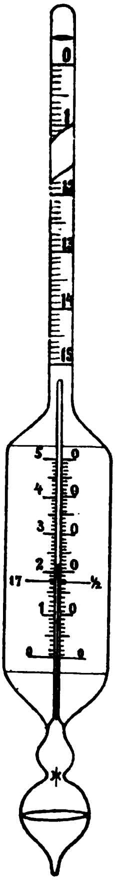

Fig. 9.

In technico-chemical analyses, the specific gravity of solutions (juices, etc.) is generally determined by means of a *hydrometer* (spindle).

These spindles, however, simply show the specific gravity of the liquid into which they are sunk, without referring to the percentage of the solids in solution, which must be calculated from special tables.

For sugar analyses, *Brix* has constructed a spindle which, if immersed in a solution of pure sugar in water, shows the percentage of sugar directly. (See Fig. 9.) Consequently if we immerse a *Brix spindle* into a solution (a pure sugar solution) containing 25 per cent. sugar, the spindle will sink until the 25 degree mark of the scale enclosed in the stem of the instrument is exactly even with the surface of the sugar solution, provided the latter has a temperature of 17½° C.

Most Brix hydrometers have a thermometer in their main body and if the temperature of the solution is above or below the normal of 17½° C. as indicated by this thermometer, a correction of the reading of the spindle is required. (See Brix temperature correction table, Chapter XVI.)

A Brix spindle with the corrections already calculated and marked on the scale of the thermometer is also made, but the correction table is still in use in many sugar laboratories.

In order to find the specific gravity or the "Brix" of a juice, a tall glass cylinder is selected and filled with it. Hot juice should be previously cooled down to room temperature by immersing it in cold water, while juice containing bubbles of air should remain untouched until these have risen to the surface, there forming a layer of foam which is easily removed with the aid of a spoon. The cylinder with the juice is placed on a level table, or still better, on a so-called levelling tripod and by an adjustment of the screws, is given a perfectly level position. This adjustment is essential for correct work as the immersed hydrometer should remain in the center of the liquid and should not touch the sides of the cylinder.

A dry, clean spindle is then carefully lowered into the liquid until a point is reached where it remains stationary, *i. e.*, where the weight of the spindle coincides with the weight of the juice it displaces. A certain mark of the scale of the spindle will now be even with the surface of the juice and the reading obtained there will be the specific gravity or the Brix, depending on the kind of hydrometer used.

In reading the scale in the stem of the spindle, the eyes of the observer should be level with the surface of the juice. It will be noticed that the latter rises slightly around the stem owing to capillary attraction. This reading (upper meniscus) should be ignored but that point of the scale which is in one line (level) with the general surface of the juice will be the correct reading (lower meniscus). Fig. 10 illustrates the manner of reading a spindle, the correct reading being 18.9 and not 18.8. The line a-b forms the general surface of the juice.

Special care should be exercised in spindling "raw" beet juices. In many factories, the beets brought in by the farmer are not tested directly, but an analysis of the juice extracted therefrom is made. The cleaned, tared beets (see Chapter III) are ground or rasped to a pulp 5 or 6 handfuls are then wrapped in a piece of filter cloth and placed in the cylinder of a small juice press.

Pressure is applied and the juice thus extracted is collected in a glass cylinder.

From this juice, an accurate spindling cannot be obtained before at least half an hour has elapsed as upon close observation, it will be found to contain countless small bubbles of air.

A quicker method to remove the air is to pour the freshly made juice into a large bottle which is connected with a strong vacuum. This draws the bubbles to the surface. If the bottom of the bottle is provided with a glass cock the clear juice may thus be drawn off and is then ready to be "brixed."

Frequent mention of the degree "Baumé" has been made in previous chapters. This Baumé spindle is now used in sugar factories to find the density of thick solutions, for instance of thick juice, although it does not give any information as to the percentage of sugar nor to the specific gravity unless used with special tables.

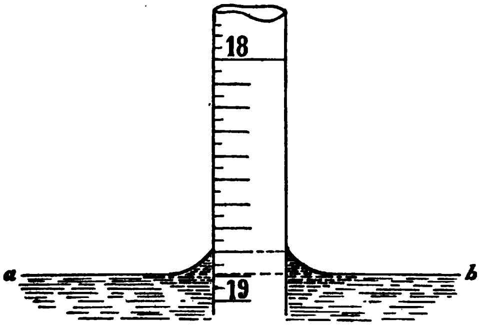

Fig. 10.

Baumé, a French chemist, simply took a 10 per cent. solution of common salt in water and called the mark of the spindle even with the surface, "10 degrees." Pure water fixed his zero point. The space between this point and 10° was divided into 10 equal parts. It is obvious that this spindle is of not much practical value in sugar analyses, and consequently its use in the laboratory is rather limited.

In case a sample is not sufficient to allow a Brix determination by the "spindle method," it is done with the aid of a *"pycnometer."* For technical analyses, a common 50 cubic centimeter graduated sugar flask may be used.

The perfectly clean, dry flask is weighed, then filled exactly to the 50 cubic centimeter mark with the juice which should have a temperature of 17½ C. and again weighed.

Example:

| | Grams |
|---|---|
| Flask with juice | 75.784 |
| Flask | 21.467 |
| Juice | 54.317 |

The specific gravity of the juice will be:

$$\frac{54.317}{50} = 1.0863$$

which corresponds to a Brix of 20.7. (See Chapter XVI, Table of comparison of Brix and specific gravity).

For very accurate work, a special "pycnometer flask" is used; but the principle of the method is the same (see Fig. 11).

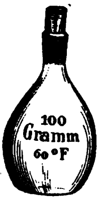

Fig. 11.

Still another very accurate method for the determination of the specific gravity of liquids is in general use: *The hydrostatic balance.*

Owing to its very limited use in the sugar laboratory, a description is deemed unnecessary. Directions of use accompany every balance.

**9. Determination of the Percentage of Sucrose.**—As beet juices always contain, besides sugar and water, a certain amount of dissolved impurities, which naturally increases the density of the juices, a Brix spindle does not only show the percentage of sugar but added to this is the amount of non-sugar (salts, etc.). The sum of the two is known as the *"dry substance"* or the *"total solids"* contained in the juice. Consequently, in such juices, a Brix spindle only shows the percentage of total solids and the percentage of sugar must be found by one of the methods given below.

**10. The "Coefficient of Purity."**—*This is the percentage of sugar contained in the "dry substance" of the juice. Or it may be termed the ratio between the percentage of total solids and the percentage of sugar. It is found by dividing the percentage of sugar by the percentage of total solids (Brix) and multiplying the result by 100.*

**11.** The Brix of a juice having been obtained and the necessary corrections for temperature made, a 100 cubic centimeter flask having two graduations (marks), one at 100 cubic centimeters and one at 110 cubic centimeters (see Fig. 12) is filled to the lower (100) mark with juice and clarification effected by adding 10 cubic centimeters of lead acetate (thus filling the flask exactly to the 110 cubic centimeter mark). After thoroughly shaking the mixture, it is allowed to stand for 2 or 3 minutes, filtered and polarized.

To the polariscopic reading, one-tenth is added (on account of the dilution with lead acetate) and the result is multiplied by 0.26048. The percentage of sugar by volume is thus obtained (grams of sugar in 100 cubic centimeters). The percentage by weight is obtained by dividing the percentage by volume by the specific gravity corresponding to the Brix of the juice.

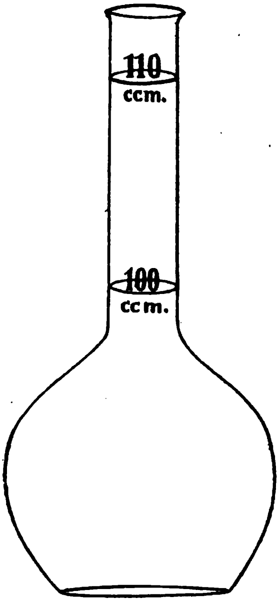

Fig. 12.

In order to do away with all these calculations, *Schmitz* has calculated a very useful table (see Chapter XVI, Table III). The following example illustrates the use of this table:

Example:

A thin juice brixed 12.4 (corrected for temperature by Table

1) and with the 100/110 cubic centimeter method, a reading of 41.2 has been obtained.

Looking up the Brix and specific gravity column in Schmitz's table we find 12.0 as the nearest number to the Brix of the juice, and in the polariscopic reading column, 41.0 as the nearest to the reading obtained. Where the two columns meet the number 11.18 will be found. But the Brix of the juice is 12.4 instead of only 12.0 and as this lies between 11.5 and 22.5, we look up the small "tenths" Brix table corresponding to the above numbers and find opposite 0.4 Brix the number corresponding to the per cent. sugar.

This number (0.11) added to 11.18 gives us 11.29 per cent. sugar by weight.

The coefficient of purity of the juice is then found by dividing the sugar by the Brix and multiplying by 100.

$$\frac{11.29}{12.4} \times 100 = 91.05.$$

**12. Errors Caused by the Addition of Lead Acetate.**—By adding lead acetate for the purpose of clarification, the precipitate formed is often of considerable magnitude (especially with very impure sugar solutions) and gives rise to errors, as the flask filled to the required mark also contains the precipitate and thus actually holds an amount of liquid less than the volume shown by the mark. Consequently, the solution will be slightly stronger and give higher results in the polariscope. Scheibler has worked out the following method to correct this error: A 100/110 cubic centimeter flask is filled to the lower mark with juice, 10 cubic centimeters of lead acetate added, thoroughly mixed, filtered and polarized.

Another 100 cubic centimeters of juice are now measured out, 10 cubic centimeters of lead acetate added and the whole diluted to 220 cubic centimeters with water, filtered and polarized. The second reading is doubled, subtracted from the first, the difference multiplied by 2.2 and the product subtracted from the first reading.

Example:

First reading ............ 40.0
Second reading .......... 19.8
19.8 × 2 =.............. 39.6
First reading — 39.6 =... 0.4
0.4 multiplied by 2.2 =... 0.88
First reading — 0.88 =... 39.12 which is the correct reading.

**13.** Still another method for the determination of sugar in juices is largely employed. It consists of "brixing" the juice, weighing out the *normal weight* in a nickel dish, washing it into a 100 cubic centimeter flask and adding a sufficient quantity of lead acetate. The flask is then filled to the 100 cubic centimeter mark with water, the contents thoroughly mixed by shaking, filtered and polarized in a 200 millimeter tube. The percentage of sugar will thus be found directly. The percentage of sugar divided by the Brix gives the purity of the juice.

**14. Sucrose Pipette Method.**—The following method of determining the sugar consists of brixing the juice and drawing up 52.096 grams into a special pipette (*Spencer's*), the stem of which is graduated, generally from 0 to 25.0 Brix. If this pipette is filled to the graduation corresponding to the Brix uncorrected) of the juice, it will contain exactly 52.096 grams. Consequently, at the zero mark it will contain 52.096 of pure water. (See Fig. 13.)

The juice in the pipette is allowed to run into a 100 cubic centimeter flask and lead acetate added, filled to the 100 cubic centimeter mark with water, mixed, filtered and polarized. The reading divided by 2 (on account of the double normal weight to the normal flask) gives the percentage of sugar.

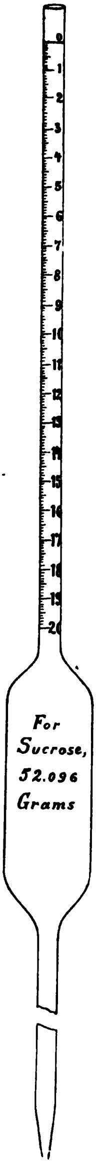

Fig. 13.

This method is less accurate but can be used for beet juice tests where a large number of samples must be handled in a comparatively short time. In American factories it is largely used for all kinds of juice tests.

**15. Determination of the Percentage of Water and Non-Sugar.**— Twenty-five grams of ignited, dried quartz sand are weighed out in a small flat-bottomed porcelain dish, including a small glass rod placed in the dish. The accurate weight of the whole arrangement having been determined 10 cubic centimeters of juice are added and the total weight is found. The dish is placed on the water-bath and under frequent stirring with the glass rod most of the juice evaporated.

The dish with the residue is then transferred to a drying oven and the residue dried to constant weight. By careful stirring with the glass rod a homogeneous mass is effected and an even evaporation thus assured. (Without the use of quartz sand, a sticky, pasty sirup from which the last traces of water could only be expelled with the greatest difficulty, would remain).

Example:

| | Grams |
|---|---|
| Dish, sand, rod and juice | 50.219 |
| Dish, sand and rod | 39.941 |
| Juice | 10.278 |
| Dish, sand, rod and residue after drying | 41.986 |
| Weight of the water expelled | 8.233 |

10,278 grams of juice contained 8.233 grams of water or 80.1 per cent. and consequently 19.9 per cent. dry substance.

The percentage of *non-sugar* contained in the juice is found by deducting the percentage of sugar, as determined by one of the methods described, from the percentage of dry substance.

**16. Determination of the Coefficient of Purity.**—The dry substance as found by the Brix spindle cannot be accepted as perfectly correct, as the non-sugar influences the spindle in a different way than sucrose. For instance 1 per cent. of lime contained in the juice is able to cause an increase of nearly 3° Brix. It is on account of this unreliability of the spindle that the purity found by the Brix method is termed *"apparent"* purity.

In order to find the *"true"* purity, the dry substance as found by *drying* must be used.

Example:

| | Per cent. |
|---|---|
| Dry substance as found by evaporation | 19.9 |
| Sugar found by the 100/110 cubic centimeter method | 17.2 |

17.2 divided by 19.9 and the result multiplied by 100 gives a "true" purity of 86.4

17.2 divided by 19.9 and the result multiplied by 100 gives a "true" purity of 86.4.

**17. Determination of the Percentage of Salts.**—This is determined by a complete incineration of a weighed quantity of juice in a platinum dish with the addition of sulphuric acid.

Twenty grams of juice are weighed out in a platinum dish and evaporated to a very small volume on the water-bath. From 20 to 30 drops of concentrated sulphuric acid are then added to the residue. After a few minutes the dish is heated to dull redness over a large Bunsen burner and after thorough charring has taken place, is removed to a muffle where the remaining "coke" is completely burned off at a temperature of about 750° C. (dull redness), until a perfectly white ash remains in the dish.

After cooling in a desiccator, the residue is weighed. Ten per cent. must be deducted from the weight of the "ash," owing to the higher molecular weight of the sulphates that are formed by the addition of sulphuric acid.

Example:

| | |
|---|---|
| Platinum dish and juice | 34.628 |
| Dish | 24.628 |
| Juice | 20.000 |
| Platinum dish with ash | 24.737 |
| Dish | 24.628 |
| Ash | 0.109 |
| Minus 10 per cent. allowance for sulphates | 0.0109 |
| Salts | 0.0981 |

This multiplied by 20 and divided by 100 gives 0.3962 per cent. salts contained in the juice.

**18. Determination of the Alkalinity.**—The alkalinity of thin juices must be determined frequently and is of great importance in the carbonation and suphitation process.

It is estimated with *normal* or *tenth-normal acid* by titration. (For preparation, see Chapter XV.)

Phenolphthalein is generally employed as an indicator. In neutral or acid solutions this indicator is colorless but the faintest excess of an alkali produces a bright-red color.

*A normal acid is a solution of acid in water; and a liter contains the equivalent weight of the active element in grams.* This also applies to normal alkali solutions.

A normal solution of sulphuric acid therefore contains 49 grams (the molecular weight of sulphuric acid is 98) of the pure acid to the liter, hydrogen being the active element. In this case, the molecular weight must be divided by 2 in order to obtain its equivalent weight: 1.

A normal solution of hydrochloric acid contains the full molecular weight (36.5 grams) to the liter, as here only one atom of hydrogen is present.

In preparing a normal sodium hydrate solution ($NaOH$) a liter must contain 40 grams of the salt, the sodium being the active element.

The alkalinity is generally determined in grams of $CaO$ per liter of juice. As 1 cubic centimeter of a normal acid solution corresponds to 0.028 gram of $CaO$, the number of cubic centimeters of acid used to neutralize a certain quantity of juice must be multiplied by 0.028 in order to find the quantity of $CaO$.

It has been found more convenient to do away with these calculations and to prepare an acid 1 cubic centimeter of which corresponds to exactly 0.01 gram of $CaO$.

For this purpose, 1,000 cubic centimeters of normal acid (prepared according to directions given in Chapter XV) and consequently corresponding to 28 grams of $CaO$ are diluted with exactly 1,800 cubic centimeters of distilled water and thoroughly mixed by shaking.

The 2,800 cubic centimeters of acid now correspond to 28.0 grams of CaO, or 1 cubic centimeter to 0.01 gram of CaO.

Ten cubic centimeters of juice are generally taken for the determination. They are measured out with a 10 cubic centimeter pipette and transferred to a porcelain dish. A 50 cubic centimeter burette fastened to a stand is filled to the zero mark with the above prepared acid and the dish with the juice placed under it. Two or three drops of phenolphthalein solution are then added to the juice and while stirring with a glass rod the acid is added drop by drop until the red color of the juice produced by the indicator has entirely disappeared. The number of cubic centimeters of acid required to accomplish this result, multiplied by 0.01 gives the amount of CaO in the sample.

A very rapid and accurate method for the man in charge of the carbonation to determine the alkalinity of the juice is the following:

An *"indicator acid"* is prepared by substituting a small part of the water used to dilute the normal acid to "factory acid" (see Chapter XV) with alcoholic phenolphthalein solution.

The strength of the acid thus prepared is the same, but if some of it is added to an alkaline juice, the latter is colored red until the point of neutrality is reached.

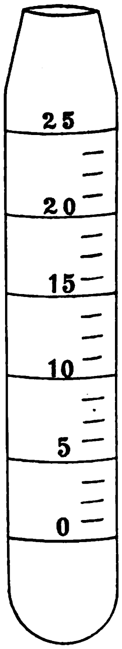

Fig. 14.

A special graduated tube invented by *Vivien* (see Fig. 14) is used for these determinations.

The indicator acid (1 cubic centimeter = 0.001 gram of CaO) is diluted with an equal volume of water and is then ready for use. In order to compensate for this dilution, Vivien's tube is graduated in such a way that every degree reads off 1 cubic centimeter but actually corresponds to 2 cubic centimeters.

The space at the bottom of the tube is filled with the previously filtered juice up to the ero mark and the indicator acid is added in small portions from a syphon bottle. After each addition the tube is closed with the finger and well shaken. This is repeated until the red color at first obtained, disappears, thus indicating that neutrality is reached, or in other words, that sufficient acid has been added. The number of cubic centimeters of acid required for the decolorization is the alkalinity of the juice in hundredth volume per cent. of CaO.

The indicator acid is prepared by measuring out 18 cubic centimeters of normal sulphuric acid by means of a pipette, transferring to a 1,000 cubic centimeter flask, adding 500 cubic centimeters of distilled water, then 25 cubic centimeters of alcoholic phenolphthalein solution and finally filling up to the 1,000 cubic centimeter mark with distilled water.

This acid should be renewed every week as owing to its diluteness it is apt to deteriorize.

**19. Determination of the Hardness.**—It is a well-known fact that the calcium compounds contained in the juices have a disadvantageous effect upon the boiling and granulation process and a constant control of this is essential.

The determination is made with the aid of a *standard soap solution.* This soap solution is titrated by means of a barium chloride solution, 1 cubic centimeter of which corresponds to 0.0001 gram of CaO.

The reaction is complete with the formation of a dense persistent lather and the soap solution is thus titrated that 10 cubic centimeters of the barium chloride solution require exactly 1 cubic centimeter of soap solution to produce the above reaction. (The preparation of the solutions is described in Chapter XV.)

The standardization of the soap solution is effected as follows:

By means of a pipette, 50 cubic centimeters of barium chloride solution are run into the "foam bottle," which has a capacity of about 200 cubic centimeters and bears a mark at 100 cubic centimeters. The bottle is then filled to the 100 cubic centimeter mark with distilled water.

The special burette is filled to the zero mark with the soap solution and by holding it in an inclined position, a few drops are carefully run into the barium solution and thoroughly mixed with the latter by vigorous shaking after the stopper has been inserted.

These small additions of soap solution with subsequent shaking are continued until a layer of fine lather remaining for at least 5 minutes without re-shaking, is obtained.

As mentioned before, 10 cubic centimeters of barium solution should require exactly 1 cubic centimeter of soap solution, consequently 50 cubic centimeters should require 5 cubic centimeters, in this case, to produce the persistent foam.

We will suppose that the persistent foam was obtained after only 3.8 cubic centimeters of soap solution had been added. This indicated that the soap solution is too strong and must be diluted. By the equation we find:

$$3.8 : 5.0 = x : 1{,}000$$

that 760 cubic centimeters of the soap solution placed in a 1,000 cubic centimeter flask and diluted to the 1,000 cubic centimeter mark with alcohol, will give us a solution of the required strength. This must be verified by another titration.

Example:

Ten cubic centimeters of juice are measured out, emptied into the foam bottle and diluted to 100 cubic centimeters with distilled water.

3.5 cubic centimeters of soap solution were required to produce the known reaction. As one cubic centimeter equals 0.001 gram of CaO, 3.5 cubic centimeter for 10 cubic centimeter of juice will equal 0.035 per cent.

**20.** Another method for the determination of the hardness, based upon the same principle, is recommended. Here, the foam bottle has graduations at 10, 20, 30 and 40 cubic centimeters capacity and has a total capacity of about 100 cubic centimeters to allow ample space for shaking the mixture.

The soap solution for this method is standardized with a barium nitrate solution (preparation, see Chapter XV), 40 cubic centimeters of which should require exactly 22° of the soap solution added from a special burette (see illustration No. 15).

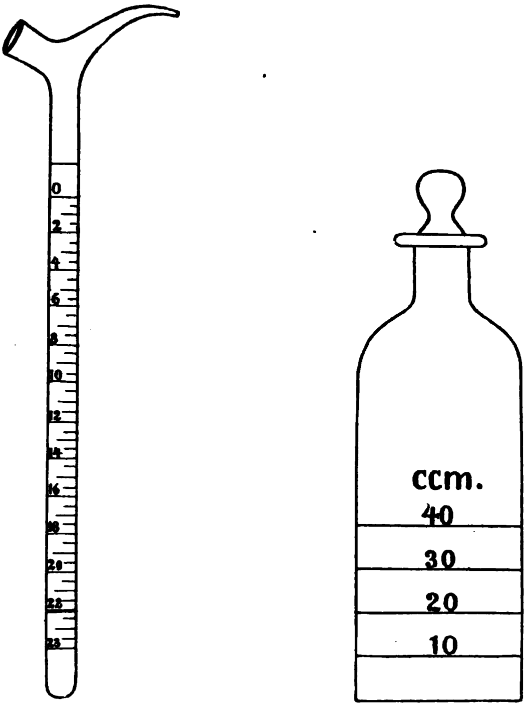

Fig. 15.

In this method, every degree of soap solution used to produce the persistent lather, corresponds to 0.0228 gram of CaO per liter of juice.

## CHAPTER VI

## THE ANALYSIS OF MASSECUITES, MOLASSES, THICK JUICES AND SIRUPS.

**21. Determination of the Specific Gravity and the Brix.**—Products like the above, having a high density cannot be accurately brixed by the spindle method, but if this method has to be followed a certain quantity of the thick product is diluted with a certain quantity of hot water in such a proportion that by a simple multiplication, the original Brix (density) can be ascertained.

Otherwise, it is best to use the *"pycnometer"* method as described in Chapter V. A small 50 cubic centimeter sugar flask will serve the purpose very well and the correct weight of the contents, multiplied by 2 and divided by 100 will give the specific gravity. With the aid of Table II, Chapter XVI, the corresponding Brix will then be found.

Molasses and sirups often contain a large number of small bubbles and must be submitted to a special treatment before the pycnometer method can be employed. It consists of carefully heating the molasses until all the bubbles have risen to the surface. This, however, requires time and is not very often used in technical analyses. The description of a Brix method which is very convenient and sufficiently accurate will follow here:

Two hundred grams of the product are weighed out in a previously tared beaker and about 100 grams of hot distilled water added. The mixture is then stirred well with a glass rod or spoon until all has dissolved, whereafter the beaker is placed in cold water (room temperature). After the contents are cooled it is again placed on the scale and cold water added until the total weight of the water added equals the weight of the sample taken for analysis. The contents of the beaker is then poured into a glass cylinder and the Brix determined and corrected for temperature, if required, in the usual way. The Brix thus obtained, multiplied by 2 gives the Brix of the original product.

The proportion of water and juice can naturally be altered and 2, 3, 4 or 5 parts of water used to one part of thick product, but the Brix thus obtained will have to be multiplied the required number of times and the fact should be borne in mind, that the greater the dilution, the more room is left for errors.

**22. Determination of the Percentage of Sucrose.**—*The use of this method necessitates a sample of juice, etc., that does not contain any optically active bodies besides sucrose.*

Exactly 26.048 grams of thick product (molasses see further down) are weighed out in a nickel scoop and by means of hot water and with the aid of a glass rod dissolved without spilling, and carefully washed into a 100 cubic centimeter sugar flask. After this has been done, the flask is immersed in cold water and the contents cooled to about room temperature. Lead acetate is then added in sufficient quantity. This is ascertained when a few drops of it running down on the side of the flask which is held in an inclined position, produce no further precipitate. A small quantity of alumina cream (preparation see Chapter XV) also added to the solution in the flask after it has been clarified with lead acetate aids greatly in producing a clear filtrate.

The flask is now filled to the 100 cubic centimeter mark with water (foam, if any, thrown down with a few drops of ether) the contents thoroughly mixed by shaking, filtered and polarized as usual. The reading obtained gives the percentage of sugar directly.

*The determination of sucrose in molasses,* owing to the dark color of the product is generally effected as follows:

26.048 grams are weighed out and carefully washed into a 200 cubic centimeter flask with hot water. After cooling in cold water the flask is filled to about four-fifths its capacity with it and lead acetate and alumina cream added for clarification. Great care should be exercised to add enough of these and at the same time to avoid an excess. The flask is then filled to the 200 cubic centimeter mark with water, well shaken and the contents filtered and polarized. The reading thus obtained is multiplied by 2.

**23. Determination of the Percentage of Sucrose in the Presence of Raffinose.**—This determination is made as described in Art. 36. The second portion (for inversion) is clarified by means of 1 to 2 grams of animal charcoal after completing the volume to 100 cubic centimeters with water. After adding this and thoroughly shaking the contents, at least 15 minutes time should be given for clarification by the charcoal and then filtered and polarized. In these tests, the temperature of the solution during polarization, is very important and observations should only be made with the aid of an *"inversion tube."* This is a tube surrounded by an outer jacket through which water of exactly 20° C. is made to circulate in order to keep the solution at that temperature during the entire manipulation. (See Fig. 16.)

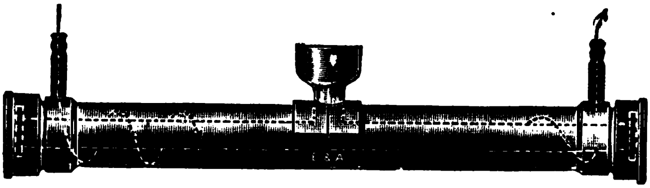

Fig. 16.

To find the percentage of sucrose, the following formula is employed:

$$\frac{(0.5124\ P') + P''}{0.8390} = S$$

$P'$ = The polarization before inversion (common method: 26.048 grams to 100 cubic centimeters solution).

$P''$ = The polarization after inversion, multiplied by 2, owing to the half-normal weight used.

$S$ = The percentage of sucrose.

**24.** Should *the percentage of sucrose in the presence of "dextrose"* be required, the following (Clerget's) formula must be used, the above method of work remaining the same. (The rotative power of dextrose is not changed by the addition of hydrochloric acid, which, however, is the case with raffinose.)

$$\frac{100 \times P}{132.66^1} = S$$

or

$$0.7538 \times P = S$$

S = Sucrose
P = Total decrease of polarization (neglecting the minus sign).

**25. Determination of the Percentage of Sucrose in the Presence of Invert sugar (in large quantities).**—If after a qualitative test for invert sugar (Art. 44) it was found to be present in the sample in large quantities (more than 2 per cent.), the determination is made by the inversion method (Art. 36) and with the use of the dextrose formula (Art. 24).

Sucrose in the presence of *small* quantities of invert sugar is determined as usual (Art. 22) but with the addition of very little lead acetate; an excess should be avoided under all circumstances. A quantitative test for invert sugar is then made according to Art. 45 and 46.

**26.** If a sample was found to contain large quantities of invert sugar and was analyzed by the optical inversion method (see Art. 25) with Clerget's formula, *the quantity of invert sugar* contained in the sample can be calculated from the data obtained as above, with the aid of the following formula:

$$\frac{(S - P) \times 100}{32.66} = I.$$

I = Invert Sugar.
S = Sucrose (as found by Clerget's formula).
P = Polarization before inversion.

---

[1] The number 132.66 originates from the following: A pure sucrose solution (normal weight to 100 cubic centimeters) polarizes 100° in the Ventzke scale polariscope and the same solution, after total inversion —42.66°, so that P equals 142.66 at 0° C. As now, with every increase of 1° C. in temperature, the polarization of invert sugar decreases 0.5 and as the observations are made at 20° C., 10 must be deducted from 142.66 leaving 132.66.

**27. Determination of the Percentage of Water and Non-Sugar.**—This determination is made exactly according to directions given in Art. 15. The addition of quartz sand is very essential in this case owing to the high density and more or less sticky, pasty condition of the samples.

About 5 grams should be used for the determination. The dish with the mixture of sand and product is placed in the drying oven for about a quarter of an hour and with the aid of a glass rod, the hot sand and the juice, massecuite or molasses is well mixed until a homogeneous, but dissolute mass is obtained. (It should under no circumstances become pasty as this would indicate that not sufficient sand was used.) The glass rod remains in the mixture and the dish is returned to the drying oven when constant weight is generally obtained in 7 to 8 hours at a temperature of 110° C.

Example:

| | Grams |
|---|---|
| Dish, sand, glass rod and sample | 76.466 |
| Dish, sand and glass rod | 71.466 |
| Sample | 5.000 |
| After drying 8 hours | 75.684 |
| | 76.466 |
| | 75.684 |
| Water | 0.782 |

5.000 : .782 :: 100 : X  X = 15.64 per cent. water.

**28. The Percentage of Non-Sugar** is then calculated from the above (see Art. 27) as follows:

Assumed: 72.50 per cent. sucrose were found in the sample. We will have 72.50 plus 15.64 = 88.14 per cent. total solids and this deducted from 100, leaves 11.86 per cent. non-sugar.

**29. Determination of the Coefficient of Purity.**—The "true" coefficient of purity can be calculated from the above results (Art. 27 and 28) by the following equation:

88.14 : 72.50 :: 100 : X  X = 82.3 "true purity."

If the *total solids* had been determined by the "spindle" method the purity thus calculated would be the "apparent purity."

**30.** In case a massecuite, molasses or sirup is simply to be tested for *apparent purity,* as is often required; it is only necessary to dissolve a quantity in hot water until a solution of about 17-20 Brix is obtained.

This is cooled to near normal temperature, the Brix taken, corrected if necessary and the normal weight of this solution then weighed out, washed into a 100 cubic centimeter flask, clarified, filtered and polarized.

Example:

The Brix of a massecuite after dilution was found to be 17.3 (corrected). The polariscopic reading obtained from this solution was 15.1. Consequently, the apparent purity of the massecuite is:

$$17.3 : 15.1 :: 100 : X \qquad X = 87.3.$$

**31. Determination of the Percentage of Salts.**—This is made according to directions given in Art. 17, but only 3 grams of the substance are taken, and after the addition of sulphuric acid, a thorough mixture is obtained by stirring with a platinum wire. The wire is then cleaned with very small pieces of ashless filter paper which are afterwards thrown into the dish, in order to avoid any loss.

After completely burning off the "coke" in the muffle, the weight of the remaining white ash is simply multiplied by 30 and the percentage of salts thus found. Before this is done, however, one-tenth of the weight should be deducted (see Art. 17) to allow for the weight of the sulphuric acid.

**32. Determination of the Alkalinity.**—Twenty grams of the substance are weighed out and by means of hot distilled water dissolved and transferred to a porcelain dish. A few drops of neutral litmus solution are then added to the sample and while the solution is being stirred with a glass rod, normal acid is added drop by drop until the point is reached where a drop of acid in excess will cause the solution to change to purple-red.

**33. Some Solutions are too Dark** for the above method and the change of color is not perceptible. In such a case, the point of neutrality is ascertained with small strips of neutral litmus paper. The solution is examined with these, after each addition of acid and the required number of cubic centimeters of normal acid noted as soon as a strip immersed begins to turn red.

The weight of the CaO in grams, contained in the sample is found by multiplying the number of cubic centimeters of acid required, by 0.0028 providing *"one-tenth normal"* acid was used.

**34. Determination of the Hardness.**—This is done as described in Arts. 19 and 20.

It is generally assumed that thick juices with from 0.05 to 0.20 per cent. (10 to 20 grams of CaO in 100 cubic centimeters) "hardness," are best adapted to be boiled to grain while such with 0.25 per cent. or more boil "heavy" and often must be boiled "blank." This, however, should never be the case, except when very bad, unripe or rotten beets are being worked.

## CHAPTER VII

### THE ANALYSIS OF SUGARS.

**35. Determinaton of the Percentage of Sucrose. (Ordinary Method)**.—The sample of sugar should be well mixed with the hands and should not contain any lumps. Then 26.048 grams are weighed in a German silver scoop and with some hot water and the aid of a glass rod washed into a 100 cubic centimeter flask. The best way is to first dissolve all the sugar in the scoop before it is transferred to the flask. The scoop must be rinsed out very carefully and the washings added to the contents of the flask, so that not a trace of material is lost.

About 20 to 30 drops of lead acetate and a few cubic centimeters of alumina cream are then added. (White sugar merely requires an addition of alumina). Any foam that may have formed is removed by a drop of ether and the flask filled to the 100 cubic centimeter mark with water; well mixed by shaking, filtered and polarized.

**36. Determination of the Percentage of Sucrose in the Presence of Raffinose.**—The presence of raffinose is indicated by an unnaturally high polarization of the product. (The presence of *dextrose* causes a very strong reduction of Fehling's solution.) Raffinose is often met with in sugar work and gives rise to a peculiar needle-like shape of the sugar crystals.

Owing to the high specific rotation of raffinose, sugar house products containing it, polarize too high and the *"true"* polarization must be determined by special methods.

*In order to obtain accurate results, the following directions should be followed closely, special care should be given to the weighing and temperatures.*

26.048 grams of the sample are weighed out and the polarization determined according to Art. 35. The "inversion tube" which is surrounded by a water-jacket *must* be used here, care being taken to keep the temperature of the solution during observation at *exactly* 20° C. (See Fig. 16.)

A second portion of the original sample of only 13.024 grams is now weighed out, dissolved and carefully (without loss) washed into a 100 cubic centimeter flask using about 75 cubic centimeters of hot distilled water to accomplish this. Exactly 5 cubic centimeters of hydrochloric acid specific gravity 1.188 are now added, and well mixed with the sugar solution by slowly rotating the flask. It is then placed in a water-bath previously heated to 70° C. Here it remains for 10 minutes while the temperature of the bath is watched closely and the solution kept well mixed by giving the flask a slow circular motion.

At the end of 10 minutes, the flask is removed and immediately placed in another water-bath containing water of normal temperature where the contents is cooled as rapidly as possible. It is then filled to the 100 cubic centimeter mark with water of the same temperature and should the solution be a dark one, about one gram of animal charcoal is added for the purpose of decolorization and well shaken. After 10 or 15 minutes the thus inverted solution is filtered and polarized in the above mentioned "inversion tube" a temperature of exactly 20° C. being kept up during observation.

The percentage of sucrose is found with the aid of the following formula:

$$\frac{(0.5124\ P') + P''}{0.8390} = S.$$

Example:

A sample of sugar polarized before inversion 94.2; after inversion 13.4.

$$\frac{\left[0.5124 \times 94.2\right] + \left[2 \times \overset{P''}{13.4}\right]}{0.8390} = 89.5 \text{ per cent. sucrose.}$$

**37. Determination of the Percentage of Sucrose in the Presence of Invert Sugar.**—If the substance contains large quantities of invert sugar, the determination is made by the optical inversion method Art. 36 and with Clerget's formula (see also Art. 24).

$$0.7538 \times P = S.$$

"P" being the total decrease of polarization. (If, for instance

94.2 was the polarization before inversion and —13.4 after inversion, the "total decrease of polarization" will be:

$$94.2 + (2 \times 13.4) = 121.00.$$

**38.** The determination of sucrose in the presence of *smaller* quantities of invert sugar is generally effected by polarizing a sample as described in Art. 35, taking care to avoid an addition of lead acetate in excess. A separate determination of the quantity of invert sugar is made with Fehling's solution.

**39. Determination of the Percentage of Water and Non-Sugar.**—Exactly 5 grams of a sugar (10 grams of a very dry product) are weighed out in an evaporating dish and placed in the drying oven kept at 105° C., where constant weight is generally obtained after 1 to 2 hours. The temperature should be watched closely and should not rise above 110° C. to avoid charring of the sugar.

**40. The Percentage of Non-Sugar** is obtained as in Art. 27 and 28.

**41. Determination of the Percentage of Ash and Salts.**—The residue after incineration of a sugar, containing the impurities (sand, etc.,) is called "ash" and after these impurities are removed the remaining portion is known as "salts."

The latter consist mainly of alkali chlorides, sulphates and carbonates. As alkali salts generally withhold particles of carbon from combustion, and the strong heat during the ignition of sugar may cause the chlorides to volatilize, the incineration is best conducted as follows:

Twenty grams of sugar are charred in a large platinum dish until the evolution of gas ceases. By means of a small pestle, the remaining "coke," previously moistened with water, is then crushed to a fine paste. After adding a little more water and heating, the mixture is filtered and the residue on the filter thoroughly washed with hot water. Filter and residue are then dried and completely incinerated in a clean platinum dish.

The white residue is moistened with a few drops of ammonium carbonate, the filtrate obtained as above added, and the entire contents evaporated to dryness on a water-bath.

The pure-white residue is then weighed and calculated as the percentage of "ash."

**42.** *The Determination of the Percentage of "Salts"* is conducted as follows:

Twenty-five grams of sugar are dissolved in 250 cubic centimeters of hot, distilled water and 200 cubic centimeters of the turbid solution ( = 20 grams of sugar) evaporated in a large platinum dish, charred, and treated as described in Art. 41.

It is evident that the terms "ash" and "salts" of an absolutely pure white sugar are analogous.

**43.** *To Determine the Salts or Ash of a Perfectly Pure White Sugar* (a sugar that gives a clear solution when dissolved in hot water) Scheibler's method is successfully employed. A description of this method will be found in Art. 17 and 31. Three grams of sugar is a convenient quantity for this method.

### DETERMINATION OF INVERT SUGAR (Gravimetric Methods).

**44. Qualitative Determination.**—20 grams of the product (molasses, raw sugars, sirups, etc.,) are dissolved in water in a 100 cubic centimeter flask, lead acetate added for clarification and the flask filled to the mark with water. The solution is then filtered and 50 cubic centimeters of the filtrate mixed with an equal volume of Fehling's solution. After boiling for 2 minutes, the formation of a precipitate of red cuprous oxide indicates the presence of invert sugar.

**45. Quantitative Determination.**—An "approximate" quantitative test must be made if the presence of invert sugar was established as in the preceding article:

Ten grams of the sample are dissolved in water, washed into a 100 cubic centimeter flask, clarified with lead acetate, filled to the 100 cubic centimeter mark and filtered.

Each cubic centimeter of this solution now contains 0.1 gram of the sample.

Quantities of 2, 4, 6, 8 and 10 cubic centimeters are now transferred to separate test tubes, 5 cubic centimeters of Fehling's solution added to each tube and the contents boiled. Special notice should be taken of that tube, the contents of which "nearly decolorize." If, for instance, this is the case with the tube containing the 10 cubic centimeters of sugar solution, it indicates the presence of less than 1.5 per cent. of invert sugar in the sample and the final determination is then made according to "Herzfeld's method." If, however, the amount of invert sugar exceeds 1.5 per cent. "Meissl & Hiller's method" must be employed (Art. 47).

**46. Herzfeld's Method for the Quantitative Determination of Invert Sugar.**—26.048 grams of the sample are weighed, transferred to a 100 cubic centimeter flask, clarified with lead acetate and if necessary, the excess of lead precipitated with sodium carbonate solution.

For this purpose 46.07 cubic centimeters of the above sugar solution are diluted to 60 cubic centimeters with concentrate sodium carbonate solution and filtered. Fifty cubic centimeters (equal to 10 grams of the sample) of the filtrate are then used for the determination.

In case the precipitation with sodium carbonate is *not* required, 38.4 cubic centimeters of the original filtered sugar solution are diluted to 50 cubic centimeters. This also corresponds to 10 grams of the sample.

The 50 cubic centimeters obtained by this or the other method are placed in an Erlenmeyer flask, together with 50 cubic centimeters of freshly mixed Fehling's solution (25 cubic centimeters F. No. 1 and 25 cubic centimeters F. No. 2), and heated to boiling over a large Bunsen burner.

The solution should be kept boiling for exactly 3 minutes figuring from the time, when the bubbles begin to rise from the bottom and also from the sides of the flask.

At the end of this time, the flask is removed; 100 cubic centimeters of cold, distilled water added immediately and the contents rapidly filtered without loss through a previously washed, dried and weighed *"asbestos filter tube"* connected to a filter pump. Fig. 17 illustrates such an asbestos filter tube.

The precipitate of cuprous oxide, remaining on the asbestos is then rapidly washed with about 300 cubic centimeters of hot distilled water, then with alcohol and finally, in order to remove the last traces of the latter, with ether.

The tube containing the asbestos filter with the residue is now placed in the drying oven at 125° C., for a short time only. It is then removed and heated to a low red heat over a Bunsen burner to oxidize all organic matter. After these manipulations the residue is ready to be reduced to metallic copper.

For this purpose, the asbestos filter is connected with an H gas generator (Kipp's) and a strong current of the washed and dried gas passed through while the tube is being heated to redness.

The reduction should be completed in a few minutes; this point is indicated when the moisture collecting in the lower end of the tube has disappeared and the gas emanating from the end of the tube can be lighted and remains burning (caution).

After extinguishing the flame (by pinching the rubber tube connecting with the gas generator), the tube is allowed to cool in a current of the gas, then placed in a desiccator and weighed after about 15 minutes. The increase in weight is the weight of the copper.

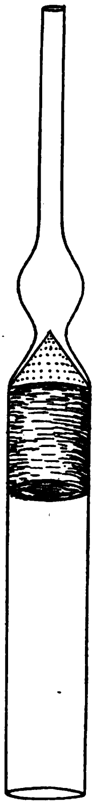

Fig. 17.

In case the above mentioned asbestos filter tube is not at hand, a common paper filter (ashless, analytical) can be used for the determination. The filter paper with the washed residue is then placed in a platinum crucible having a perforated lid (Rose's crucible, see Fig. 18) and

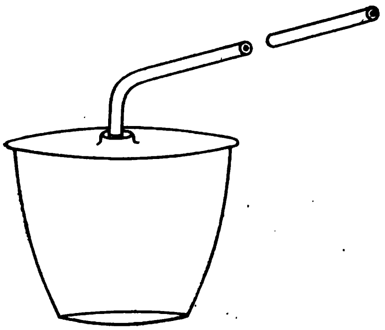

Fig. 18.

incinerated and reduced in the current of H gas in the same manner as described above.

From the weight of the copper obtained, the percentage of invert sugar is found with the aid of the following table:

Cu = amount of copper in milligrams. Per cent. I. S. = corresponding per cent. invert sugar.

HERZFELD'S TABLE.

| Cu | Per cent. I. S. | Cu | Per cent. I. S. | Cu | Per cent. I. S. | Cu | Per cent. I. S. | Cu | Per cent. I. S. |
|---|---|---|---|---|---|---|---|---|---|
| 50 | 0.05 | 105 | 0.32 | 160 | 0.62 | 215 | 0.93 | 270 | 1.24 |
| 55 | 0.07 | 110 | 0.35 | 165 | 0.65 | 220 | 0.96 | 275 | 1.27 |
| 60 | 0.09 | 115 | 0.38 | 170 | 0.68 | 225 | 0.99 | 280 | 1.30 |
| 65 | 0.11 | 120 | 0.40 | 175 | 0.71 | 230 | 1.02 | 285 | 1.33 |
| 70 | 0.14 | 125 | 0.43 | 180 | 0.74 | 235 | 1.05 | 290 | 1.36 |
| 75 | 0.16 | 130 | 0.45 | 185 | 0.76 | 240 | 1.07 | 295 | 1.38 |
| 80 | 0.19 | 135 | 0.48 | 190 | 0.79 | 245 | 1.10 | 300 | 1.41 |
| 85 | 0.21 | 140 | 0.51 | 195 | 0.82 | 250 | 1.13 | 305 | 1.44 |
| 90 | 0.24 | 145 | 0.53 | 200 | 0.85 | 255 | 1.16 | 310 | 1.47 |
| 95 | 0.27 | 150 | 0.56 | 205 | 0.88 | 260 | 1.19 | 315 | 1.50 |
| 100 | 0.30 | 155 | 0.59 | 210 | 0.90 | 265 | 1.21 | | |

**47. Meissl and Hiller's Method.**—If the amount of invert sugar in the sample exceeds 1.5 per cent., the following method is generally used:

The number of grams to be employed is here also found by the "approximate quantitative test," described in Art. 45.

Every cubic centimeter of a sugar solution corresponds to 0.1 gram of substance in these preliminary tests and in Meissl & Hiller's method, ten times the quantity of sugar and Fehling's solution is used. Consequently every cubic centimeter in the test tubes corresponds to 1.0 gram of substance if the final determination is to be made according to Meissl & Hiller's method. Thus, if the test tube containing 4 cubic centimeters of solution is nearly decolorized, 4 grams of substance dissolved in 50 cubic centimeters of water must be used.

Double the quantity as found by the preliminary test—in the example 4 x 2 grams—are weighed, dissolved in water, washed into a 100 cubic centimeter flask without loss, clarified, filled to the 100 cubic centimeter mark with water, filtered and 50 cubic centimeters of the filtrate treated as described for Herzfeld's method.

In this case, the following "table of factors" must be used:

### MEISSL AND HILLER'S TABLE OF FACTORS.

| Ratio C: I | I = 0.200 | I = 0.175 | I = 0.150 | I = 0.125 | I = 0.100 | I = 0.075 | I = 0.050 |
|---|---|---|---|---|---|---|---|
| 0 : 100 | 56.4 | 55.4 | 54.5 | 53.8 | 53.2 | 53.0 | 53.0 |
| 10 : 90 | 56.3 | 55.3 | 54.4 | 53.8 | 53.2 | 52.9 | 52.9 |
| 20 : 80 | 56.2 | 55.2 | 54.3 | 53.7 | 53.2 | 52.7 | 52.7 |
| 30 : 70 | 56.1 | 55.1 | 54.2 | 53.7 | 53.2 | 52.6 | 52.6 |
| 40 : 60 | 55.9 | 55.0 | 54.1 | 53.6 | 53.1 | 52.5 | 52.4 |
| 50 : 50 | 55.7 | 54.9 | 54.0 | 53.5 | 53.1 | 52.3 | 52.2 |
| 60 : 40 | 55.6 | 54.7 | 53.8 | 53.2 | 52.8 | 52.1 | 51.9 |
| 70 : 30 | 55.5 | 54.5 | 53.5 | 52.9 | 52.5 | 51.9 | 51.6 |
| 80 : 20 | 55.4 | 54.3 | 53.3 | 52.7 | 52.2 | 51.7 | 51.3 |
| 90 : 10 | 54.6 | 53.6 | 53.1 | 52.6 | 52.1 | 51.6 | 51.2 |
| 91 : 9 | 54.1 | 53.6 | 52.6 | 52.1 | 51.6 | 51.2 | 50.7 |
| 92 : 8 | 53.6 | 53.1 | 52.1 | 51.6 | 51.2 | 50.7 | 50.3 |
| 93 : 7 | 53.6 | 53.1 | 52.1 | 51.2 | 50.7 | 50.3 | 49.8 |
| 94 : 6 | 53.1 | 52.6 | 51.6 | 50.7 | 50.3 | 49.8 | 48.9 |
| 95 : 5 | 52.6 | 52.1 | 51.2 | 50.3 | 49.4 | 48.9 | 48.5 |
| 96 : 4 | 52.1 | 51.2 | 50.7 | 49.8 | 48.9 | 47.7 | 46.9 |
| 97 : 3 | 50.7 | 50.3 | 49.8 | 48.9 | 47.7 | 46.2 | 45.1 |
| 98 : 2 | 49.9 | 48.9 | 48.5 | 47.3 | 45.8 | 43.3 | 40.0 |
| 99 : 1 | 47.7 | 47.3 | 46.5 | 45.1 | 43.3 | 41.2 | 38.1 |

$Cu$ = Weight of copper obtained.

$P$ = Polarization of the sample.

$W$ = Weight of sample used in 50 cubic centimeters of solution.

$F$ = Factor from table.

$\frac{Cu}{2}$ = Approximate absolute weight of invert sugar = $S$.

$S \times \frac{100}{W}$ = Approximate per cent. invert sugar = $Y$.

$\frac{100\,P}{P + Y}$ = Relative number for cane sugar = $C$.

$100 - C$ = Relative number for invert sugar = $I$.

$\frac{CuF}{W}$ = True percentage of invert sugar.

Example:

The polarization of a sugar is 89.9 (according to Art. 36). The preliminary test showed that the test-tube with 6 cubic centimeters of sugar solution was nearly decolorized, while from that which contained 8 cubic centimeters, the blue color had disappeared.

Consequently 6.0 grams of the substance were taken; they were found to be equivalent to 0.250 gram of copper.

$$\frac{Cu}{2} = \frac{0.250}{2} = 0.125 = S$$

$$S \times \frac{100}{W} = \frac{100}{6} + 0.125 = 2.08 = Y$$

$$\frac{100 \times 89.9}{89.9 + 2.08} = 97.73 = C$$

$$100 - 97.73 = 2.27 = I$$

$$C : I :: 97.73 : 2.27$$

By looking up the table we find in the vertical column, headed $1 = 0.125$, the nearest (in this case equal) to S. In the ratio column, we find 98:2 the nearest to 97.73 : 2.27. Where the two columns meet, we find the factor $F = 47.3$.

$$\frac{CuF}{W} = \frac{0.250 \times 47.3}{6} = 1.97 \text{ per cent. invert sugar.}$$

**48. Titration Method with Fehling's Solution.**—The percentage of invert sugar in beet and diffusion juices is often determined by the volumetric method with Fehling's solution. From the results of this method, the percentage of sucrose can also be calculated.

Fehling's solution consists of two solutions *viz.* F. No. 1 and F. No. 2, the former blue and the latter colorless. Equal quantities of the two are mixed, shortly before they are to be used.

*Fehling's solution is standardized as follows*:

9.50 grams of chemically pure cane sugar (see Chapter XV) are dissolved in a 100 cubic centimeter (metric) flask and the solution inverted according to Art. 36.

The inverted solution after cooling and filling up to the 100 cubic centimeter mark then contains exactly 10 grams of sugar (owing to the combination with one molecule of water.)

Fifty cubic centimeters of this solution (5 grams of invert sugar) are drawn into a 1,000 cubic centimeter flask and sodium carbonate solution added until a small piece of red litmus paper thrown into it, turns blue thus indicating that the acid is neutralized. The flask is then filled to the 1,000 cubic centimeter mark with distilled water. A pinch-cock burette, graduated in tenths of cubic centimeters is fastened to a stand and filled with the solution, one cubic centimeter of which corresponds to 0.005 gram of invert sugar.

Exactly 25 cubic centimeters of F. No. 1 are now pipetted into a large porcelain dish, exactly 25 cubic centimeters of F. No. 2 and finally 50 cubic centimeters of water added and the mixture heated to boiling. The invert sugar solution is then added slowly in small portions and after the addition of each portion the solution is brought to boiling and well stirred with a glass rod.

The additions of invert sugar are continued until, after the precipitate has settled, the blue color of the solution is just beginning to disappear.

A number of qualitative side tests are made with a cold saturated solution of potassium ferrocyanide, strongly acidified with acetic acid, while the invert sugar solution is added slowly, drop by drop. The following test is made in short intervals to watch the progress of the reduction.

With the aid of the glass rod a drop of the potassium ferrocyanide solution is transferred to a small piece of white filter paper and a drop of the boiling solution placed near it. The point where both drops meet upon spreading, is observed and if a reddish brown line does not appear too much of the invert sugar solution had been added and the entire titration must be repeated. If, however, a reddish-brown precipitate is formed, some more invert sugar solution is carefully added to the boiling Fehling's solution, and the side-test repeated.

When a point is reached where, with *as small an excess of invert sugar solution as possible,* the line where both drops meet remains colorless thus indicating that the entire amount of Fehling's solution is decomposed, the number of cubic centimeters of invert sugar solution used, is recorded. Owing to the drop of solution adhering to them, the small pieces of filter paper used for the side-tests should be thrown into the solution in the porcelain dish to avoid losses.

Great care should be exercised when measuring F. No. 1 and

F. No. 2 to have the same number of drops run off from the pipette after emptying same, in every subsequent test.

As above mentioned, one cubic centimeter of invert sugar solution contains 0.005 gram of invert sugar. If, for instance, 49 cubic centimeters have been used and this number was found to be correct by a subsequent titration, we know that 49 × 0.005 = 0.2450 gram of invert sugar were necessary to completely reduce the 50 cubic centimeters of Fehling's solution.

*The actual determinations of invert sugar and sucrose are conducted in the same manner as described above.*

13.024 grams of the substance to be tested are inverted as in Art. 36, 50 cubic centimeters are then transferred to a 1,000 cubic centimeter flask, neutralized with sodium carbonate solution, the flask filled up to the mark with distilled water and the burette filled with this solution.

Exactly 25 cubic centimeters of F. No. 1 and 25 cubic centimeters of F. No. 2 are taken, 50 cubic centimeters of water added and proceeded as in the above described "standardization."

Example:

Determination of sucrose.

A sirup has been inverted according to directions. One cubic centimeter of the sirup solution in the burette should then correspond to 0.006512 gram of sirup.

The Fehling's solution was found to be of such a strength that 0.2450 gram of invert sugar completely reduced 50 cubic centimeters.

We will suppose that, in this case, 67 cubic centimeters of inverted sirup were required for the reduction. Consequently, these 67 cubic centimeters should also contain 0.2450 gram of invert sugar.

Sixty-seven cubic centimeters contain 67 × 0.006512 gram = 0.4363 gram of sirup.

$$0.4363 : 0.2450 :: 100 : x$$

X = 56.38 per cent. invert sugar contained in the sirup after inversion.

**49.** This number, multiplied by 0.95[1] gives the percentage of sucrose. 53.46 per cent. sucrose contained in the sirup.

**50.** It is sometimes required to determine the percentage of invert sugar in diffusion juice. *Claassen's method* for this determination is conducted as follows:

Ten grams of pure sugar are dissolved in water and the volume completed to 500 cubic centimeters.

9.5 grams of pure cane sugar are then inverted according to Art. 36 and filled up to the mark (100 metric cubic centimeters). Ten cubic centimeters of this solution are diluted to 500 cubic centimeters with water, thus giving a solution, one cubic centimeter of which contains 0.002 gram of invert sugar.

The Fehling's solution is "standardized" as follows:

Ten cubic centimeters of Fehling's solution (5 : 5) are accurately measured out, transferred to a 250 cubic centimeter flask, 50 cubic centimeters of the above prepared sugar solution and corresponding to 1 gram of sugar (approximate amount contained in 10 cubic centimeters of diffusion juice, as used in the actual test) added, the mixture heated to boiling and titrated with the invert sugar solution prepared as above, as described in Art. 48. The number of cubic centimeters required for the reduction is recorded and used in the actual determination.

**51.** 100 cubic centimeters of diffusion juice are clarified with lead acetate (10 cubic centimeters) and filtered. 55 cubic centimeters of the filtrate corresponding to 50 cubic centimeters of the diffusion juice are pipetted into a 250 cubic centimeter flask, the excess of lead precipitated with sodium carbonate, filled to the mark and filtered.

Fifty cubic centimeters (= 10 cubic centimeters of juice) of this filtrate are then removed to a beaker, 10 cubic centimeters of freshly mixed Fehling's solution (5 : 5) added, heated to boiling for 2 minutes and titrated as described in Art. 48.

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[1] 0.95 parts of sucrose are required for the formation of 1 part of invert sugar.

Example:

Ten cubic centimeters of Fehling's solution required 19.8 cubic centimeters of the invert sugar solution for the complete reduction. Ten cubic centimeters of diffusion juice required 15 cubic centimeters of the same solution.

19.8 minus 15.0 = 4.8. One cubic centimeter of the invert sugar solution contains 0.002 gram of invert sugar, then 4.8 cubic centimeters contain 0.96 gram or 0.96 per cent. of invert sugar is contained in the diffusion juice.

**52. Determination of the Percentage of Raffinose.**—Assumed that the presence of raffinose in a product necessitated the use of the *"optical inversion"* method, Art. 36. The polarization is determined according to Art. 35 and another portion inverted as above. The following formula is employed in the calculation:

$$\frac{(0.5124\ P') + P''}{0.8390} = S.$$

The sucrose having thus been determined, the following formula gives the percentage of raffinose contained in the sample:

$$\frac{P - S}{1.852} = \text{per cent. raffinose.}$$

**53. Determination of the Percentage of Sucrose in the Presence of both Raffinose and Invert Sugar.**—The above determination is sometimes desired, especially in factories working with a process of recovering sugar from final molasses.

13.024 grams of substance are inverted according to Art. 36 and polarized at exactly 20° C. = (P).

Fifty cubic centimeters of the filtrate are diluted to 1,000 cubic centimeters and 25 cubic centimeters of this solution (0.1628 gram of the original substance) submitted to the quantitative determination of "total sugar contents" according to Art. 46 = (Cu').

Two grams of the original substance are then taken for the "quantitative invert sugar determination" according to Art. 46 = (Cu").

C = Milligrams of sucrose as found with Cu' in Table 1.

R = Milligrams of anhydrous raffinose as found with the nearest number to Cu′ in Table II.

F′ = Factor for inverted sucrose.

F″ = Factor for inverted raffinose.

$$\frac{Cu'}{C} = F' \qquad \frac{Cu'}{R} = F''$$

Z = Total sugar contents (inverted sucrose plus invert sugar originally present, calculated as sucrose).

Raff. = Raffinose percentage.

$$\frac{582.98 \times Cu' - P \times F''}{0.9491 \times F' + 0.3266 \times F''} = Z$$

$$1.053 \times P + 0.344 \times Z = \text{Raff.}$$

Example:

13.024 gram of a final molasses are inverted, polarized at 20° C. and "P" found to be -9.0. The "total sugar" with 50 cubic centimeters of this inverted solution was determined according to Art. 46 and (Cu′) found to be 0.190 gram. Two grams of the original substance were then submitted to a quantitative invert sugar determination according to Art. 46 and (Cu″) established as 0.240 gram.

By looking up Table I, we find:

$$\frac{Cu'}{C} = \frac{0.190}{96.2} = 1.97 = F'$$

and, in Table II, we find:

$$\frac{Cu'}{R} = \frac{183.6}{130} = 1.41 = F''$$

and

$$\frac{582.98 \times 0.190 - (-9.0 \times 1.41)}{0.9491 \times 1.97 + 0.3266 \times 1.41} = 53.0 \text{ per cent.} = Z$$

$$1.053 \times -9.0 + 0.344 \times 53.0 = 8.75 \text{ per cent. Raff.}$$

With the aid of the formula of Art. 47, the percentage of invert sugar can be calculated from the above data (Cu″) by substituting 53.00 ( = Z) for "P" in the formula (Art. 47) and using Meissl & Hiller's Table.

## TABLE I.

### HERZFELD'S AND PREUSS'.

| Cu′ milligrams | C milligrams | Cu′ milligrams | C milligrams | Cu′ milligrams | C milligrams | Cu′ milligrams | C milligrams | Cu′ milligrams | C milligrams |
|---|---|---|---|---|---|---|---|---|---|
| 79 | 40.0 | 116 | 58.3 | 153 | 77.0 | 189 | 95.7 | 225 | 114.8 |
| 80 | 40.5 | 117 | 58.8 | 154 | 77.5 | 190 | 96.2 | 226 | 115.4 |
| 81 | 41.0 | 118 | 59.3 | 155 | 78.0 | 191 | 96.7 | 227 | 115.9 |
| 82 | 41.5 | 119 | 59.8 | 156 | 78.5 | 192 | 97.2 | 228 | 116.4 |
| 83 | 42.0 | 120 | 60.2 | 157 | 79.0 | 193 | 97.7 | 229 | 117.0 |
| 84 | 42.5 | 121 | 60.7 | 158 | 79.6 | 194 | 98.3 | 230 | 117.5 |
| 85 | 42.9 | 122 | 61.2 | 159 | 80.1 | 195 | 98.8 | 231 | 118.1 |
| 86 | 43.4 | 123 | 61.7 | 160 | 80.6 | 196 | 99.3 | 232 | 118.6 |
| 87 | 43.9 | 124 | 62.2 | 161 | 81.1 | 197 | 99.8 | 233 | 119.2 |
| 88 | 44.4 | 125 | 62.8 | 162 | 81.6 | 198 | 100.4 | 234 | 119.7 |
| 89 | 44.9 | 126 | 63.3 | 163 | 82.1 | 199 | 100.9 | 235 | 120.3 |
| 90 | 45.4 | 127 | 63.8 | 164 | 82.6 | 200 | 101.4 | 236 | 120.8 |
| 91 | 45.9 | 128 | 64.3 | 165 | 83.2 | 201 | 101.9 | 237 | 121.3 |
| 92 | 46.4 | 129 | 64.8 | 166 | 83.7 | 202 | 102.5 | 238 | 121.8 |
| 93 | 46.8 | 130 | 65.3 | 167 | 84.2 | 203 | 103.1 | 239 | 122.4 |
| 94 | 47.3 | 131 | 65.8 | 168 | 84.7 | 204 | 103.6 | 240 | 122.9 |
| 95 | 47.8 | 132 | 66.3 | 169 | 85.2 | 205 | 104.1 | 241 | 123.5 |
| 96 | 48.3 | 133 | 66.8 | 170 | 85.7 | 206 | 104.6 | 242 | 124.0 |
| 97 | 48.8 | 134 | 67.3 | 171 | 86.3 | 207 | 105.2 | 243 | 124.6 |
| 98 | 49.3 | 135 | 67.8 | 172 | 86.8 | 208 | 105.7 | 244 | 125.1 |
| 99 | 49.8 | 136 | 68.3 | 173 | 87.3 | 209 | 106.2 | 245 | 125.7 |
| 100 | 50.3 | 137 | 68.8 | 174 | 87.8 | 210 | 106.7 | 246 | 126.2 |
| 101 | 50.8 | 138 | 69.4 | 175 | 88.3 | 211 | 107.3 | 247 | 126.8 |
| 102 | 51.3 | 139 | 69.9 | 176 | 88.9 | 212 | 107.8 | 248 | 127.3 |
| 103 | 51.8 | 140 | 70.4 | 177 | 89.4 | 213 | 108.4 | 249 | 127.9 |
| 104 | 52.3 | 141 | 70.9 | 178 | 89.9 | 214 | 108.9 | 250 | 128.4 |
| 105 | 52.8 | 142 | 71.4 | 179 | 90.4 | 215 | 109.4 | 251 | 128.9 |
| 106 | 53.3 | 143 | 71.9 | 180 | 91.0 | 216 | 109.9 | 252 | 129.4 |
| 107 | 53.8 | 144 | 72.4 | 181 | 91.5 | 217 | 110.5 | 253 | 130.0 |
| 108 | 54.3 | 145 | 72.9 | 182 | 92.0 | 218 | 111.1 | 254 | 130.6 |
| 109 | 54.8 | 146 | 73.4 | 183 | 92.5 | 219 | 111.6 | 255 | 131.1 |
| 110 | 55.3 | 147 | 73.9 | 184 | 93.1 | 220 | 112.2 | 256 | 131.7 |
| 111 | 55.8 | 148 | 74.5 | 185 | 93.6 | 221 | 112.7 | 257 | 132.2 |
| 112 | 56.3 | 149 | 75.0 | 186 | 94.1 | 222 | 113.2 | 258 | 132.8 |
| 113 | 56.8 | 150 | 75.5 | 187 | 94.6 | 223 | 113.7 | 259 | 133.3 |
| 114 | 57.3 | 151 | 76.0 | 188 | 95.1 | 224 | 114.3 | 260 | 133.9 |
| 115 | 57.8 | 152 | 76.5 | | | | | | |

## TABLE II.

### HERZFELD'S AND PREUSS'.

| Cu' milli-grams | R milli-grams | Cu' milli-grams | R milli-grams | Cu' milli-grams | R milli-grams | Cu' milli-grams | R milli-grams | Cu' milli-grams | R milli-grams |
|---|---|---|---|---|---|---|---|---|---|
| 19.2 | 10 | 87.5 | 60 | 156.1 | 110 | 224.9 | 160 | 294.0 | 210 |
| 32.8 | 20 | 101.2 | 70 | 169.8 | 120 | 238.7 | 170 | 307.9 | 220 |
| 46.4 | 30 | 114.9 | 80 | 183.6 | 130 | 252.3 | 180 | 321.7 | 230 |
| 60.1 | 40 | 128.6 | 90 | 197.3 | 140 | 266.1 | 190 | 335.6 | 240 |
| 73.8 | 50 | 141.3 | 100 | 211.1 | 150 | 280.2 | 200 | 349.4 | 250 |

**54. Determination of the Alkalinity.**—This is made according to directions given in Art. 18, 32 and 33.

# CHAPTER VIII

## THE ANALYSIS OF PULP (EXHAUSTED COSSETTES), WASTE WATER, LIME-CAKES AND CONDENSED WATERS.

**55. Pulp and Waste Water.**—From the results obtained from these tests, the losses during the diffusion process are calculated. The determination of the percentage of sugar in these products is therefore of great importance.

As mentioned in Chapter III, the pulp and waste water are sampled from every cell dumped. The waste water is drained off and collected under a screen placed in the pulp sample-pail about two inches from the bottom.

For analysis, the pulp is ground to small pieces in a sausage grinder care being taken not to lose any of the juice which might be pressed out during this operation. The finely ground material is then placed in a filter cloth and the juice extracted in a press similar to that used for cossettes but capable of greater pressure.

A 100-110 cubic centimeter flask is filled to the 100 cubic centimeter mark with this pulp juice, a small quantity of lead acetate and alumina cream added and the volume completed to 110 cubic centimeters with water.

The same is done with the waste water, and the solutions are filtered and polarized as usual, preferably in a 400 millimeter tube, as in low sugared products this helps to reduce any possible polarization errors.

The polarization, divided by 2, one-tenth added, and the result multiplied by 0.26048 gives the percentage of sugar in the sample. See also Table IX.

*The water contained in the fresh, exhausted pulp* is determined by weighing out 10 grams and drying at 100-110° C. to constant weight.

The methods for the analysis of cossettes (Chapter IV) are also applicable for the sugar determination in the exhausted material. In that case it is simply necessary to pass the pulp through a sausage grinder and weighing out the double normal weight to 201.35 cubic centimeter of solution. The reading thus obtained with a 400 millimeter tube, divided by 2 gives the percentage of sugar.

**56. Lime Cakes.**—The following method for the determination of the percentage of sugar in lime cakes is strongly recommended (Fruehling & Schultz), as it requires but little time and gives accurate results.

Fifty grams of the "mud" are weighed in the scoop, 15 grams of crystallized ammonium nitrate added, the mixture washed into a porcelain mortar without loss, and with the aid of the pestle and about 100 cubic centimeters of water rubbed to a fine paste. This is then carefully washed into a 200 cubic centimeter flask, 10 to 20 drops of lead acetate added, filled to the mark with water, filtered and polarized.

The ammonium nitrate decomposes the saccharate, forming calcium nitrate and setting free the sucrose and ammonia, while calcium carbonate remains in the precipitate.

Observation tubes made of brass are strongly attacked by this solution and tubes of glass should be used exclusively.

With the above method, the percentage of sugar in the cake is found directly; the use of only 50 grams instead of the double normal weight is derived from the following facts:

The specific gravity of calcium carbonate is 2.9. Ordinary lime cake contains about 50 per cent. of it; 50 grams consequently contain 25 grams, which occupy a volume of 8.62 cubic centimeters as found by calculation. On account of this, after filling to the 200 cubic centimeter mark, the flask contains only 191.38 cubic centimeters of solution and the quantity of cake to correspond to this volume is 49.85 grams. The small difference between this number and 50 grams is of no consequence to the final result.

Instead of ammonium nitrate, *acetic acid* is often used to set the sugar free.

**57. Condensed Waters.**—Frequent examination for sugar should be made, as otherwise the condensed waters may increase the losses "unaccounted for," or sugar might get into the boilers.

A qualitative test is made with a solution of *alpha-naphthol.* About 2 cubic centimeters of the water are placed in a test tube, 4 or 5 drops of alpha-naphthol added (20 per cent. solution), and well shaken. About 5 cubic centimeters of chemically pure concentrate sulphuric acid are then added very slowly, so that the acid runs down the side of the tube which is held in an inclined position, the water forming a layer on top of the acid, which, of course, is much heavier and sinks to the bottom.

If a dark violet ring appears where both liquids meet, the water contains sugar and the amount present can be judged from its thickness and intensity of color.

This reaction is very sensitive as little as 0.001 per cent. of sucrose thus being detected.

Nitric acid destroys the reaction and therefore, the water and the sulphuric acid should be entirely free of it.

**58. The quantitative determination of sugar** is conducted as follows:

One hundred cubic centimeters of water are clarified with lead acetate, the volume completed to 110 cubic centimeters, filtered and polarized.

The reading plus one-tenth and multiplied by 0.26048 gives the percentage of sugar.

# CHAPTER IX

## THE ANALYSIS OF SACCHARATES.

**59.** Saccharates are classified as calcium, barium, lead or strontium saccharates depending on the process used for the recovery of sugar from the final molasses. The first and last mentioned are the ones largely employed. The analyses of all these saccharates are analogous.

**60. The determination of sucrose in the solid saccharates** is conducted as follows:

26.048 grams of the saccharate are weighed out, washed into a mortar and rubbed to a fine paste. After adding a little phenolphthalein as an indicator, acetic acid is added until the red color disappears. The solution becomes hot and assumes a dark color. A large excess of acid should be avoided.

After this neutralization, the saccharate is washed into a 200 cubic centimeter flask, a few drops of sodium carbonate added, cooled, clarified with lead acetate, filled to the mark with water, filtered and polarized.

**61. The percentage of CaO in solid saccharates** is often required and is determined in 5 grams of substance, washed into a porcelain dish and diluted to about 200 cubic centimeters with water. Phenolphthalein is then added as an indicator and the solution titrated with normal acid (preferably hydrochloric or nitric acid).

The number of cubic centimeters of acid required, multiplied by 0.028 gives the amount of CaO (0.0518 for SrO).

If, for example, 5 grams of saccharate cake were used and 21 cubic centimeters of acid were required to obtain neutrality, $21 \times 0.028 = 0.588$ gram of CaO are contained in 5 grams of cake, or $20 \times 0.588 = 11.76$ per cent. CaO.

**62. With strontium saccharate,** the titration is conveniently made with ¾ normal acid (750 cubic centimeters of normal acid diluted to 1,000 cubic centimeters with distilled water). One cubic centimeter then corresponds to 0.1 gram of crystallized strontium hydrate.

**63.** The analysis of *other products,* as for instance in the Steffen's process, the percentage of sugar in the *"cooler solution," "waste water," "wash water,"* etc., are conducted as usual. All of these, however, must be neutralized with acetic acid before clarification by lead acetate, in order to set free the sugar.

The percentage of sugar found in the "waste water," here constitutes the loss during the process and consequently, constant control should be kept.

In order to watch the efficiency of the filter presses, the percentage of sugar in the *"waste water from cooler"* is determined. This waste water is obtained by filtering a portion of the cooler solution sample through filter paper. The percentage of sugar in this filtrate is generally about 0.10 per cent. lower than in that obtained from the presses.

**64. The analysis of saccharate milk** (as used for the carbonation). The determination of the *purity* of the saccharate milk requires some special preparation of the sample. The milk is diluted to about 5° Baumé to make several liters of solution and is then carbonated in a small tank with carbonic acid gas, to neutrality. The gas is either used as obtained from the limekiln or is especially prepared from marble and dilute hydrochloric acid in "Kipp's" generator. It is washed before use by passing it through water in a gas wash-bottle.

After the saturation, the milk is placed on a water bath containing boiling water, and heated until the soluble bicarbonate of calcium is decomposed to the insoluble carbonate.

The precipitate is separated by filtration through cloth while hot and the filtrate is then evaporated to a sirup in a small vacuum pan.

The coefficient of purity of this sirup is obtained as usual.

Neutralization with acetic acid is, of course, not required in this case.

**65. The percentage of "grit"** in the powdered lime used in the coolers of the Steffen's process is determined as follows:

A weighed quantity of powdered lime is passed through a

150 or 200 mesh sieve. That portion which is unable to pass through the sieve is weighed and constitutes the percentage of grit.

**66. The percentage of CaO in powdered lime** is determined in 1 gram of material by titration with normal hydrochloric acid. The number of cubic centimeters of acid used, multiplied by 0.028 gives the amount of CaO in grams.

# CHAPTER X

## MISCELLANEOUS NOTES.

**67. General Outline of the Losses Occurring During the Manufacturing Process.**—The principal losses occurring during the manufacture of beet sugar can be classified as "mechanical" and "chemical," losses.

The latter originate more or less from the presence of dextrorotary non-sugars which cause the percentage of sugar to appear higher than what it really is.

Mechanical losses mainly originate from the waste products and are inevitable.

Hundred parts of beets give about 85 to 95 parts of wet pulp (exhausted cossettes). If the sugar determined in this pulp is = S, we have:

$$\frac{(85 \text{ to } 95) \times S}{100} = \text{the quantity of sugar lost per 100 parts of beets.}$$

If then, $S'$ = per cent. sugar in the beets, we find:

$$\frac{S \times 100}{S'} = \text{the percentage of sugar lost ``per 100 parts of sugar.''}$$

One hundred parts of beets also produce about 100 parts of waste water so that the percentage of sugar lost in this waste water is equal to the percentage of sugar lost per 100 parts of beets.

Another loss of sucrose takes place during the filtration of the "thin juice" where a small amount of sugar is retained by the lime cakes.

As an average, about 2.50 per cent. of CaO is used; 2.50 kilograms (one kilogram = 1,000 grams) produce 4.46 kilograms of CaO as found by calculation from the molecular weights.

It can be assumed that from 40 to 50 per cent. of non-sugar ("ns") is removed from the diffusion juice during the process of carbonation. Supposed, that it was estimated that 100 parts of beets give "Z" parts of diffusion juice, then we will find:

$$\frac{ns \times z \times (40 \text{ to } 50)}{100 \times 100} = Y.$$

$Y$ = Kilograms of non-sugar precipitated from 100 kilograms of beets; and

$$Y + 4.46 = L$$

$L$ = Total weight of lime and non-sugar.

The wet lime cake contains also about 50 per cent. water so that: $L \times 2 =$ kilograms of lime cake produced by 2.50 parts of lime. One part of lime will then produce:

$$\frac{(L \times 2)}{2.50} = \text{parts of lime cake.}$$

If "S" = the percentage of sugar found in the cake, we find:

$$\frac{(L \times 2) \times S}{100} = \text{percentage of sugar lost in the lime cakes, per}$$

100 parts of beets.

(In the washing of the filter-cloth, Pellet estimated an additional loss of about 0.05 per cent. sugar.)

Chemical losses, besides the aforementioned increase of polarization caused by dextrorotary bodies which are finally eliminated during the course of manufacture, also arise from the destructive influence of heat and water on sugar. It can be assumed that about 10 per cent. loss occurs during the boiling in the pan.

**68. Concentration and Dilution.**—Having 2 solutions of known Brix (B and B′), to determine the Brix of a mixture of the volumes V and V′ of these solutions.

$$\frac{VB + V'B'}{V + V'} = \text{Brix.}$$

**69. Calculation of Brix, Sugar and Purity.**—S = sugar; Bx = dry substance; P = purity.

$$\frac{S \times 100}{P} = Bx$$

$$\frac{Bx \times P}{100} = S$$

$$\frac{S \times 100}{Bx} = P$$

**70. Percentage Composition of a Product from its Composition by Weight.**—$s$ = parts of sugar; $n$ = parts of non-sugar; $w$ = parts of water.

Then:

$$s + n + w = z \text{ parts of product.}$$
$$z : s :: 100 : x = \text{per cent. sugar.}$$
$$z : n :: 100 : x = \text{per cent. non-sugar.}$$
$$z : w :: 100 : x = \text{per cent. water.}$$

**71. Calculation of the "Saline Coefficient."**—The saline coefficient is sometimes required and is the quantity of sucrose per unit of ash. It is found as follows:

$$\frac{\text{Per cent. sugar}}{\text{Per cent. ash}}.$$

**72. Calculation of the "Glucose Coefficient."**—The glucose coefficient, also called glucose ratio or glucose per 100 sucrose, is useful in detecting inversion during the different stages of manufacture. It is found as follows:

$$\frac{\text{Per cent. reducing sugar}}{\text{Per cent. sucrose}} \times 100.$$

**73. Calculation of the Heating Value of Coal.**—The heating value of coal may be found approximately by the following formula (Goutal-De Paepe).

Assumed that:

M = per cent. of volatile matter.

N = percentage of volatile matter as calculated from the coal which is supposed to be deprived of water and ashes (as determined by analysis).

P = calories set free by the combustion of 1 kilogram of coal.

C = percentage of fixed carbon.

A = a coefficient varying with the value of N.

$$N = \frac{100\,M}{M + C} \qquad P = \frac{8150\,C + AN}{100}$$

A = 14,000 if N = 2-12
A = 12,000 if N = 12-17
A = 11,000 if N = 17-24
A = 10,200 if N = 24-30
A = 9,400 if N = 30-35
A = 8,000 if N = 35-38
A = 7,900 if N = 38-40
A = 7,600 if N = 40-50

One "calorie" is the quantity of heat required to rise the temperature of 1 kilogram of water 1° C.

P × 1.8 = B. T. U. = heat liberated by the combustion of 1 pound of coal.

# CHAPTER XI

## THE ANALYSIS OF WATER.

For technical purposes, the following determinations are required:

The total solids, chlorine, silica, iron oxide and alumina, calcium, magnesium. sulphuric acid, alkalies and finally the hardness.

The principal, so-called "scale-forming" constituents of water are the carbonates of calcium and magnesium and the sulphate of calcium.

**74. Total Solids.**—A large platinum dish is placed on the water bath containing boiling water, and is left there for a few minutes; then removed, the water on the outside wiped off and the dish placed in a drying oven, at exactly 105° C. for 10 minutes. After cooling in a desiccator, the exact weight is determined.

This having been done, the dish is again placed on the water bath and exactly 100 cubic centimeters of the water to be evaporated poured into it. (If the dish does not hold all at once, the water is added in portions from time to time). The residue is heated for an additional 10 minutes after it appears dry. The dish is then carefully wiped off with a clean cloth, transferred to a drying oven and kept at 105° C. for 30 minutes. After cooling in the desiccator the weight of the residue is determined. Its weight in milligrams multiplied by 10, gives the milligrams of "total solids" per liter of water.

**75. Chlorine.**—100 cubic centimeters of the water are measured into a clean platinum dish, a few drops of potassium chromate solution added and the titration effected by means of a standard silver nitrate solution. The reaction taking place is as follows:

Each drop of silver nitrate solution added, produces a red color at the point of contact with the water and potassium chromate. On stirring, this precipitate comes in contact with more chlorine which immediately removes the silver from it destroying the red color of the chromic acid and forming silver chloride.

When all the chlorine is precipitated, an additional drop of silver nitrate will give the solution a permanent reddish color thus indicating the end of the reaction.

From the number of cubic centimeters of silver solution required, the amount of chlorine per 100 cubic centimeters of water is calculated.

One cubic centimeter of the normal silver nitrate solution corresponds to 0.0355 gram of chlorine or to 0.0585 gram of sodium chloride.

$$NaCl + AgNO_3 = NaNO_3 + AgCl$$
$$K_2CrO_4 + 2\ AgNO_3 = KNO_3\ Ag_2CO_4$$

**76. Silica.**—From 1 to 5 liters of water, depending on the amount of total solids found (**74**), are evaporated to dryness on a platinum dish.

The evaporation can be started over a Bunsen burner to save time, but when reduced to a rather small bulk, it should be completed on the water-bath.

After all moisture is driven off, the residue must be heated to 125° C. until hydrochloric acid odors are no longer perceptible. After that, the residue is thoroughly moistened with hydrochloric acid, about 30 cubic centimeters of distilled water added to dissolve the salts and heated to boiling. The solution is now filtered, the residue washed with hot water, and ignited and weighed as usual.

If a considerable residue remains after this treatment it may contain besides the silica, some calcium sulphate which must be removed by the following method:

The residue is fused with sodium carbonate, the fusion dissolved in water and hydrochloric acid, the solution evaporated to dryness and the residue heated to 125° C. for some time. It is then again moistened with hydrochloric acid, about 30 cubic centimeters of water added, boiled, filtered, thoroughly washed with hot water and the weight determined.

The filtrate is heated to boiling and an excess of ammonia and then ammonium oxalate added to precipitate the calcium. After three hours this precipitate is filtered, washed, ignited in a platinum crucible and weighed as calcium oxide.

This portion of the calcium is generally contained in the water in the form of sulphate, consequently the oxide must be calculated to the latter.

**77. Iron Oxide and Alumina.**—The filtrate from the first insoluble residue is heated to boiling and a very slight excess of ammonia added, when a white precipitate indicates calcium. If this is the case, some more ammonia is added and the precipitate dissolved in a slight excess of hydrochloric acid. The solution is then again made alkaline with ammonia and the boiling continued for a few moments.

The precipitate of the "hydrates" of iron and aluminum thus formed is allowed to settle, then filtered, washed with hot water, ignited in a platinum crucible and weighed as $Fe_2O_3 + Al_2O_3$.

**78. Calcium.**—The filtrate which has now become rather large should be evaporated to a suitable volume before proceeding any further.

A few cubic centimeters of ammonia and a slight excess of ammonium oxalate are then added to the boiling filtrate, the boiling continued for a few minutes and the precipitate allowed to settle. After filtering, washing with ammoniated hot water, and igniting in a platinum crucible at an intense heat the weight of the residue as "calcium oxide" is determined.

**79. Magnesium.**—The filtrate from the ammonium oxlate is evaporated to a small bulk, and while stirring vigorously a slight excess of sodium-ammonium phosphate, then about ¼ of the volume of the liquid of strong ammonia are added, and the solution cooled rapidly.

If a precipitate begins to form *at once* upon adding the former or latter reagent, it should be done very slowly, drop by drop and the solution stirred after the addition of each drop.

After standing seven hours in a cool place, the precipitate has settled, is filtered off, washed with ⅓ strength ammonia, ignited over a large flame and weighed as magnesium pyrophosphate $Mg_2P_2O_7$.

This is then calculated to MgO (Factor 0.36036).

**80. Sulphuric Acid.**—From one to three liters of water are acidulated with hydrochloric acid, evaporated to a small bulk and finally to dryness on a water bath. The residue is moistened with hydrochloric acid dissolved in water, the silica if any, filtered and thoroughly washed with hot water. The filtrate is then heated to boiling, a slight excess of barium chloride added and the boiling continued for a few minutes. After the precipitate has settled, it is filtered, washed, ignited moderately and weighed as barium sulphate.

From the weight obtained, the amount of $SO_3$ per liter is calculated (Factor 0.3429). If a paper filter is used, it is necessary to dry and remove the precipitate from the paper before ignition and burn the latter separately to avoid reduction by the burning paper. The dried residue is then added to the filter-ash and the whole ignited as usual.

**81. Alkalies.**—From one to three liters of water are acidulated with a few drops of hydrochloric acid and evaporated to about 75 cubic centimeters volume. A saturated solution of barium hydrate is then added until all is precipitated, the liquid heated to boiling, the precipitate filtered, and washed until a side test of the washings acidified with nitric acid gives no longer the reaction for hydrochloric acid upon adding silver nitrate.

The filtrate is now evaporated to about 75 cubic centimeters volume, and a few drops of ammonia and finally strong ammonium carbonate solution added, as long as a precipitate forms. After allowing the solution to stand for some time, while stirring occasionally, the precipitate will become granular, and is now filtered and thoroughly washed with water containing very small amounts of ammonia and ammonium carbonate. The entire filtrate, after adding a few drops of hydrochloric acid, is evaporated to dryness on the water bath, then heated in the drying oven at 100° C., finally at 135° C. The residue is heated very carefully over a Bunsen burner to dull redness to expel the ammonium salts, then dissolved in 10 cubic centimeters of water, gently heated and a few drops of barium hydrate, ammonia and a slight excess of ammonium carbonate added.

This solution is, with occasional stirring, allowed to stand for some time; filtered and the residue washed with water containing very little ammonium carbonate and ammonia.

After adding a few drops of hydrochloric acid, the filtrate is evaporated to dryness in a weighed platinum dish, at first on the water bath, then in the drying oven at 100° C., the temperature being slowly raised to 140° C. The residue is heated very carefully over a Bunsen burner to expell the ammonium salts, cooled in the desiccator and weighed as "chlorides of sodium and potassium."

In order to separate the chlorides, this residue is dissolved in a small quantity of water an excess of a solution of platinum chloride (as nearly neutral as possible) added and the solution evaporated to a "pasty consistency" on a water bath which is "just about" but not quite, boiling. After cooling, 35 cubic centimeters of 80 per cent. alcohol are added to the residue and the dish with its contents allowed to stand in a moderately warm place for about an hour while stirring occasionally.

If the residue is large it is filtered through a dried (at 120° C.) filter paper, washed thoroughly with 80 per cent. alcohol, dried at 120° C. and the weight of the potassium-platinum chloride, $K_2PtCl_6$ determined.

A very small residue is, after filtering and washing with alcohol, dissolved in a little water, the solution washed into a weighed platinum dish, evaporated to dryness on the water bath, heated to 125° C. in a drying oven and weighed as potassium-platinum chloride as above.

This is calculated to potassium chloride (Factor 0.30658) deducted from the weight of both chlorides as previously obtained and the weight of the sodium chloride thus found.

The chlorides are finally calculated to $K_2O$ (Factor 0.63087) and $Na_2O$ (Factor 0.52991).

**82. Hardness**—The determination of the hardness of water is effected by means of a standard soap solution in a similar manner as in the juice determinations.

In this case, the soap solution is titrated with a barium chloride solution, containing 0.538 gram of the salt per liter.

Forty cubic centimeters of this latter solution should require exactly 22° of soap solution from the special burette. One "degree" then corresponds to exactly 0.001 gram of calcium carbonate in 100 cubic centimeters of water, or, which is the same thing, one part in 100,000 parts.

The "total hardness" is determined in 40 cubic centimeters of water as described above and the required number of "degrees" of the soap solution are recorded.

The "permanent hardness" is found by boiling 250 or 500 cubic centimeters of water in a beaker for about half an hour, keeping up the volume by adding from time to time. After cooling it is transferred to a flask and the volume completed to exactly 250 or 500 cubic centimeters as the case may require.

After mixing and filtering, the "permanent hardness" is determined as described above for "total hardness."

If, by quantitative analysis, the amount of calcium and magnesium oxides has been found, the hardness of the water can be calculated from these data by multiplying the amount of magnesium oxide contained in 100,000 parts, by 1.388 in order to obtain an amount equivalent to CaO. The amount thus found must then be added to the actual amount of CaO present. The sum constitutes the "total hardness."

# CHAPTER XII

## THE ANALYSIS OF LIMESTONE.

A good limestone suitable for the purification of juices should not contain more than 0.40 per cent. of gypsum and only very small quantities of magnesia and the alkalies.

**83. Silica.**—One gram of the finely ground sample, previously dried at 125° C. in the oven, is placed in a porcelain dish and 25 cubic centimeters of water added. The dish is then covered with a watch glass and 15 cubic centimeters of hydrochloric acid added. It is then carefully heated on the water-bath until effervescence ceases entirely.

After removing the watch glass and washing the liquid spattered on it back into the dish, 5 drops of concentrate nitric acid are added and the solution evaporated to dryness.

The dish is then removed to a Bunsen burner, and heat applied gently until the odor of HCl is no longer perceptible, and the calcium chloride is just beginning to fuse. Excessive heat, however, should be avoided.

Seven cubic centimeters of concentrate HCl are added to the residue, heat applied very gently to dissolve the iron salts, 50 cubic centimeters of water added to the solution and heated to boiling with constant stirring.

The solution is allowed to stand a few minutes and when the precipitate has settled, it is filtered, the residue washed thoroughly, then ignited very carefully at first, finally over an intense flame, cooled in the desiccator and weighed as silica. The residue should be nearly white.

**84. Iron and Alumina.**—The filtrate obtained as above is heated to boiling and ammonia slowly added in slight excess and with constant stirring.

A large, light colored precipitate at this point is redissolved by ½ cubic centimeter of HCl and reprecipitated with another slight excess of ammonia. (This introduces enough ammonium chloride to hold everything except iron and aluminum in solution.)

In either case, the solution is boiled a few moments taking care to have it remain distinctly, but not excessively, alkaline.

After the precipitate is settled the supernatant liquid is filtered off, the filter washed with hot water, ignited in a platinum crucible at first slowly, and finally at an intense heat, cooled in the desiccator and weighed as $Fe_2O_3 + Al_2O_3$.

**85. Calcium Carbonate.**—Should the above filtrate (from the iron and alumina) greatly exceed 300 cubic centimeters, it must first be boiled down to a suitable volume. Five cubic centimeters of concentrate ammonia and 35 cubic centimeters of a saturated solution of ammonium oxalate are then added and the boiling is continued a few moments.

After 4 hours, the solution is ready to be filtered, the filter washed thoroughly with hot water containing 10 per cent. of ammonia, and the paper and precipitate dried in an oven. The precipitate is then removed from the paper and the latter burned in a weighed platinum crucible. After cooling, the precipitate is added and the whole at first slowly, finally at a high temperature, ignited for 20 minutes.

After cooling, 3 drops of water are added and the residue is then again ignited for 20 minutes. It is then cooled in the desiccator and weighed immediately as $CaO$. This is calculated to $CaCO_3$ (Factor 1.7857).

**86. Magnesium Carbonate.**—The filtrate from the ammonium oxalate is evaporated to about 250 cubic centimeters and about 25 cubic centimeters of a saturated solution of microcosmic salt added while stirring constantly.

The solution is then cooled in ice-water and 50 cubic centimeters of concentrate ammonia added, the first part very slowly, drop by drop, with constant stirring.

The beaker is covered with a watch glass, the precipitate allowed to settle by leaving it stand for about 12 hours, then filtered and washed with a solution made by mixing 150 cubic centimeters of concentrate ammonia with 350 cubic centimeters of water and adding 50 grams of ammonium nitrate.

The precipitate is dried in an oven, removed from the paper, and the latter first burned in a platinum crucible. The precipitate is then added and ignited over a strong flame for 15 minutes.

After cooling in the desiccator it is weighed as magnesium pyrophosphate $Mg_2P_2O_7$ and calculated to MgO (Factor 0.36036) or to $MgCO_3$ (Factor 0.75676).

**87. Carbon Dioxide.**—Carbon dioxide is not very often required in a technical limestone analysis. The following method is recommended by the author as it is simple and if carefully performed, gives accurate results.

About 4.6 grams of borax-glass are placed in a weighed platinum crucible and heated until fused. The heating must be done very carefully as otherwise the borax loses rapidly in weight.

The crucible is then removed to a desiccator, cooled, and the weight of the borax determined. If it is less than 4 grams, some more borax is added so as to make it a little more than 4 grams. In this case, the mass is again fused, and after cooling, the exact weight determined. One gram of the finally powdered limestone is then added, heat applied, and by gradually increasing the temperature, the platinum crucible is heated to low redness. The same precautions as above, as to over-heating of the borax must be taken and the heating is continued until the mass is in a quite state of fusion.

After cooling in the desiccator, the weight is determined. The loss in weight represents the weight of the carbon dioxide contained in the sample.

# CHAPTER XIII

## THE ANALYSIS OF LIMEKILN AND CHIMNEY GASES.

**88.** The Orsat-Muenke apparatus is best adapted for a technical analysis of the above mentioned gases. It is easy to manipulate, always ready for use and is also sufficiently accurate for all technical determinations required in the sugar-house.

The lime kiln gas should be tested frequently, the most important determination naturally being that of $CO_2$. A gas best suited for the purification resp. carbonation of the juices should contain about 30 per cent. of $CO_2$ and about 0.5-1.0 per cent. of free O.

The apparatus consists of a graduated burette of 100 cubic centimeters capacity, surrounded by a larger glass tube forming a water-jacket to prevent changes of volume of the gas in the burette, caused by changes in temperature.

The first 45 cubic centimeters are divided into tenths cubic centimeters and the remaining 55 cubic centimeters into whole cubic centimeters. The burette-top ends in a thick capillary tube, which is fastened in the wooden frame permanently containing the entire apparatus to prevent easy breakage. The further end of the capillary is bent downward and attached to it is a small U-tube containing some cotton and having its bend filled with a little water to saturate the gas with moisture, before making the determinations. A three-way cock, connecting the capillary with the U-tube is with its rear end connected with a rubber aspirator, which fills the tube with the gas to be analyzed.

The main capillary tube has also three side-tubes, each having a glass cock and a mark below the latter. These tubes, in turn, are connected with one end of the U-shaped absorption pipettes filled with glass tubes to enlarge their acting surfaces.

The other end of the pipettes is connected to a large rubber bulb, which keeps out the oxygen of the air.

The lower end of the aforementioned gas burette is connected by means of a long rubber tube, with a bottle containing water, serving to force the gas into the pipettes and back into the burette as required. (Fig. 19 illustrates an Orsat-Muencke Gas apparatus).

The filling of the apparatus is conducted as follows:

The three absorption pipettes are disconnected, but remain in the frame, and No. 1 (the one nearest the burette) receives 110 cubic centimeters of potassium hydrate solution, of a specific gravity of 1.26 introduced with the aid of a small funnel. This pipette absorbs the *carbon dioxide*. No. 2 receives a solution of 18 grams of pyrogallol in hot water, to which 70 cubic centimeters

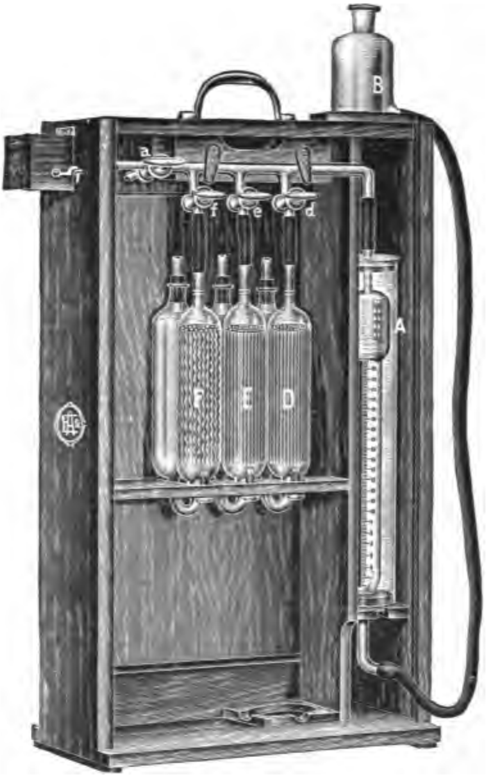

Fig. 19.

of potassium hydrate solution (1.26 specific gravity) are added and well mixed. This serves to absorb the *oxygen*. Finally, No. 3 is filled with a solution of cuprous chloride prepared by dissolving 35 grams of the salt in 200 cubic centimeters of concentrate hydrochloric acid and adding 50 grams of copper clippings. The mixture is ready to be filled into the pipette after standing 24 hours and adding 100 cubic centimeters of water. Each tube in this third pipette contains a spiral of copper wire.

The pipettes should be about half-filled with the solutions.

The three glass-cocks are now closed, the 3-way cock of the main capillary opened and by lifting the water bottle connected with the lower end of the burette, the latter is filled with water from this bottle by gravity and as the 100 cubic centimeter mark is reached, the 3-way cock is closed and the burette will remain filled, provided all rubber tube connections were made air-tight.

Now, by opening the glass cock of the first pipette, and lowering the water bottle, the solution in this pipette will be drawn up and as it rises to the mark in the capillary tube just below the cock, the latter is closed. The solutions of the 2 other pipettes are then drawn up to the mark in the same manner.

This having been done the apparatus is ready for a gas analysis.

After again filling the burette to the 100 cubic centimeter mark with water, by lifting the water bottle and opening the 3-way cock, the latter is then turned, so that connection is made with the rubber aspirator and this in turn is connected with the gas to be analyzed. By compressing the bulb a number of times in the case of chimney gases or by allowing the gas to enter by its own pressure in the case of limekiln gases, the burette is finally filled with it, the water being forced out through the connecting tube into the water bottle. When the gas has reached the zero mark, the water bottle is lowered to the same level, and as soon as equilibrium is attained, the 3-way cock is closed.

To determine the percentage of $CO_2$ contained in these 100 cubic centimeters of gas, the glass cock connecting the capillary with the first pipette (KOH) is opened and by raising the water bottle the gas is forced into it and absorption takes place, thus diminishing the volume of the gas. The water bottle is then lowered again and the gas drawn back into the burette, taking care *not* to draw the KOH solution of the pipette *above* the mark of the capillary. This is repeated 3 times, always leaving the gas in contact with the solution for a few moments by pinching the tube connecting the water bottle with the fingers, when the liquids will remain stationary.

The gas is now returned to the burette by drawing the solution up to exactly the mark in the capillary and closing the glass cock. The remaining volume of gas in the burette is again equalized with the outside atmospheric pressure by holding the water bottle close to the burette in such a way that the water stands at the same level in both vessels.

The remaining volume read off and deducted from 100 cubic centimeters gives the percentage of $CO_2$.

The oxygen and finally the CO (carbon monoxide) are absorbed in exactly the same manner. The loss of volume from the preceded reading always gives the percentage of the respective gas.

After the last absorption in the third pipette (before the last reading is obtained) the gas is returned once more to the first pipette, as the vapors of hydrochloric acid, retained in the gas from the cuprous chloride solution are thus removed.

After the third absorption, the gas still remaining unabsorbed is nitrogen and is reported as such.

If O is found by the second absorption, CO is *not* present.

The following is an average analysis of limekiln gases:

| | |
|---|---|
| Absorption in the first pipette.......... | 30.8 per cent. $CO_2$ |
| Absorption in the second pipette........ | 1.6 per cent. O |
| Consequently no CO is present.......... | 0.0 per cent. CO |
| And the residue is..................... | 67.6 per cent. N |

The following analysis of chimney gases indicates that an amount of fuel is wasted by improper management of the fires:

| | |
|---|---|
| Absorption in the first pipette | 11.2 per cent. $CO_2$ |
| Absorption in the second pipette | 0.0 per cent. O |
| Absorption in the third pipette | 1.0 per cent. CO |
| Residue | 87.8 per cent. N |

This is an analysis as it should appear:

| | |
|---|---|
| Absorption in the first pipette | 15.0 per cent. $CO_2$ |
| Absorption in the second pipette | 4.8 per cent. O |
| Absorption in the third pipette | 0.0 per cent. CO |
| Residue | 80.2 per cent. N |

**89. Sulphur dioxide** is sometimes found in the gas and the following qualitative test is generally all that is required.

The gas is passed through a solution of starch which is previously colored blue by the addition of some potassium iodide solution.

In the presence of sulphur dioxide, a gradual decolorization will take place.

**90. Hydrogen Sulphide** is detected by means of a piece of filter paper soaked in a solution of lead acetate, which will gradually turn brown if traces of hydrogen sulphide are present.

Only one of these two constituents however, can be present in the gas, as the following equation shows that they cannot exist together without undergoing decomposition.

$$SO_2 + 2H_2S = 2H_2O + 2S$$

# CHAPTER XIV

## THE ANALYSIS OF COAL AND COKE.

**91.** A good average sample of coal or coke is required. It should be finely powdered and preserved in a tightly stoppered bottle. The analysis should be performed as soon as possible after the pulverizing.

**92. Moisture.**—One gram of the powdered substance is weighed in a platinum crucible and dried in the oven at 104 to 107° C. for one hour.

The crucible is then covered, placed in the desiccator and when cool, weighed while covered. The loss in weight constitutes the "moisture."

**93. Volatile Combustible Matter.**—One gram of the powdered sample is weighed in a platinum crucible provided with a tightly fitting cover and is then heated over a large Bunsen flame, with the cover on tight, for exactly 7 minutes.

The crucible should be about 7 centimeters above the burner and draft should be avoided. After cooling in the desiccator it is weighed. From the loss of weight, the amount of moisture found in the preceding determination is deducted. The remainder is the "combustible matter" (volatile).

**94. Fixed Carbon and Ash.**— The crucible with the residue of the last determination is again heated over a Bunsen burner, the cover drawn a little to the side and the crucible placed in an inclined position, to freely admit a good supply of air.

By taking the cover off from time to time and stirring the contents of the crucible with a platinum wire, the combustion can be hastened. The heating should be started slowly or the draft may carry away particles of carbon.

After the carbon is completely burned off, the crucible is placed in a desiccator and weighed as soon as cool. The difference between this weight and the last one (volatile combustible matter) is the weight of the "fixed carbon" in one gram of material and the weight of the residue in the crucible is the weight of the "ash."

**95. Sulphur.**—The following method for the determination of sulphur is largely employed and if performed carefully, gives very accurate results. Care should be taken to only use *strictly* chemically pure reagents in this determination.

One gram of the powdered coal is thoroughly mixed by grinding it in a mortar with 9 grams of sodium carbonate and 5 grams of potassium nitrate. The mixture is then transferred to a large platinum crucible and the mortar cleaned out by grinding about one gram of sodium carbonate in it and adding this to the crucible.

After covering the crucible, it is at first gently, finally at higher temperature, heated over a large Bunsen burner, taking care by removing the cover from time to time, that the fusion does not boil over.

When the fusion is complete, it is allowed to cool and the crucible with contents placed in hot water to dissolve the fused matter out of it. After washing the former thoroughly with hot water, it is removed and the fusion boiled for some time, then filtered and the residue in the filter washed with hot water.

The filtrate is acidulated with hydrochloric acid, evaporated to dryness, the residue moistened with 5 drops of hydrochloric acid, 100 cubic centimeters of water added and heated to boiling,

The solution is then filtered, the filter washed thoroughly with hot water, the filtrate diluted to about 400 cubic centimeters and again heated to boiling. From this solution, the sulphur is precipitated by adding about 15 cubic centimeters of a solution of barium chloride (10 per cent.).

After the precipitate has settled, it is filtered off, washed, dried in an oven, removed from the paper, the latter burned, and the precipitate added and ignited moderately.

After cooling in the desiccator, the weight of the barium sulphate is determined. The filter ash is deducted; the weight of the barium sulphate multiplied by 0.1373 gives the weight of the sulphur contained in the sample.

# CHAPTER XV.

## THE PREPARATION OF SOLUTIONS, STANDARD ACIDS, ETC.

**96. Ammonium Oxalate Solution.**—1 part of the pure, crystallized salt is dissolved in 25 parts of distilled water.

**97. Ammonium Carbonate Solution.**—1 part of pure ammonium carbonate is dissolved in 4 parts of water and 1 part of concentrate ammonia added.

**98. Alumina Cream.**—1 part of aluminum chloride is dissolved in 100 parts of water and precipitated with ammonia to alkaline reaction.

The precipitate of aluminum hydrate thus formed is allowed to settle, the liquid decanted, and the precipitate washed by decantation until the alkaline reaction ceases.

The hydrate is then mixed with water in a proportion to produce a creamy liquid.

**99. Barium Nitrate Solution for Soap Tests.**—Exactly 0.59 gram of chemically pure barium nitrate are dissolved in distilled water and the volume completed to 1,000 cubic centimeters. 40 cubic centimeters of this solution should require exactly 22° of soap solution, to produce a persistent lather.

**100. Barium Chloride Solution.**—1 part of the pure chloride is dissolved in 10 parts of water.

**101. Barium Hydrate Solution.**—1 part of pure crystallized barium hydrate is dissolved in 20 parts of distilled water (hot), the solution filtered immediately and kept in a tightly-stoppered bottle.

**102. Barium Chloride Solution for Soap Tests.**—0.436 gram of the pure, dry, crystallized barium chloride are dissolved in distilled water to 1,000 cubic centimeters volume.

Forty cubic centimeters of this solution correspond to 0.004 gram of CaO.

**103. Cuprous Chloride.**—35 grams of cuprous chloride are dissolved in 200 cubic centimeters of concentrate hydrochloric acid, 50 grams of copper clippings added and the mixture allowed to stand for 24 hours.

After adding 100 cubic centimeters of water, the solution is ready for use in the Orsat-Muenke gas apparatus.

**104. Fehling's Solution.**—

"F. No. 1."

34.63 grams of copper sulphate are dissolved in 500 cubic centimeters of water.

"F. No. 2."

One hundred and seventy-three grams of sodium-potassium tartrate are dissolved in 400 cubic centimeters of water, the solution filtered, 50 grams of sodium hydrate added to the filtrate and the volume completed to 500 cubic centimeters with distilled water.

**105. Hydrochloric Acid** (normal).—1 liter of the acid contains 36.46 grams of HCl.

Two hundred cubic centimeters of pure HCl with a specific gravity of 1,100 are diluted with water to 1,000 cubic centimeters and titrated against normal sodium hydrate solution, using phenolphthalein as an indicator.

**106. Lead Acetate Solution.**—1,500 cubic centimeters of water, 465 grams of lead acetate and 265 grams of litharge are boiled for half an hour with frequent stirring. After cooling, the solution is diluted to 2 liters, the precipitate allowed to settle and the clear solution decanted.

Specific gravity should be about 1.267.

**107. Litmus Solution.**—Powdered litmus is repeatedly treated with 90 per cent. warm alcohol and the solution decanted. Hot water is added to the residue, which is then allowed to stand for 12 hours. The blue liquid is decanted.

Dilute sulphuric acid is then added until the liquid assumes a red color and while applying heat, an excess of a mixture of barium chloride and water is added, the precipitate allowed to settle, filtered and one-third of the volume of the liquid of 90 per cent. alcohol added.

The solution should be kept in a loosely covered bottle as the total exclusion of air causes deterioration.

**108. Nitric Acid** (normal).—1 liter contains 63.05 grams of $HNO_3$. About 200 cubic centimeters of strong nitric acid (about 1.20 specific gravity) are diluted with 1,000 cubic centimeters of water, and titrated against normal sodium hydrate solution. (See preparation. Art. 116.)

**109. Phenolphthalein Solution.**—1 part of phenolphthalein to 500 parts of 90 per cent. alcohol.

**110. Potassium Hydrate Solution.**—25 grams of KOH are dissolved in water to 100 cubic centimeters. The specific gravity should be between 1.26 and 1.28.

**111. Pyrogallol Solution.**—27 grams of pyrogallol are dissolved in 60 cubic centimeters of hot water, filtered, and to the cool solution 105 cubic centimeters of the above KOH solution (Art. 110) added, and well mixed.

**112. Potassium Ferrocyanide Solution.**—Some of the crystallized salt is dissolved in distilled water thus forming a lemon-yellow solution. This is then strongly acidified with acetic acid.

**113. Rosolic Acid Solution.**—1 part is dissolved in 100 parts of 90 per cent. alcohol.

**114. Silver Nitrate Solution** ($^1/_{10}$ normal).—Exactly 16.997 grams of chemically pure, fused silver nitrate are dissolved in 1,000 cubic centimeters of distilled water. One cubic centimeter of the solution corresponds to 0.00355 gram of chlorine or to 0.0058 gram of sodium chloride.

The silver nitrate solution is titrated against a solution of sodium chloride, prepared by weighing exactly 5.84 grams of pure, dry sodum chloride and dissolving it in water to exactly 1,000 cubic centimeters of solution.

A solution of potassium chromate in water is used as an indicator. (See also Chapter XI, the determination of chlorine in water.)

**115. Sugar** (chemically pure).—White, refined sugar is dissolved in hot water to a saturated solution and recrystallized by adding absolute ethyl-alcohol. The sugar is then filtered off and washed with alcohol.

The same process is repeated and the purified sugar thus obtained dried between filter paper.

**116. Sodium Hydrate Solution** (normal).—This solution should contain 40.06 grams of $NaOH$ per liter.

Sodium hydrate solution of 1.14 specific gravity is diluted with an equal volume of water and the solution thus obtained, titrated against normal sulphuric acid, using phenolphthalein as an indicator.

**117. Sulphuric Acid** (normal).—1 liter contains 49.04 grams of $H_2SO_4$ or 40.03 grams of $SO_3$.

One part of concentrate sulphuric acid is poured into 15 parts of water, while stirring the mixture constantly. After cooling, the amount of $H_2SO_4$ is determined with barium chloride solution by precipitating the sulphuric acid as barium sulphate.

These determinations should be made 2 or 3 times, to verify the results. The weight of barium sulphate found, multiplied by 0.3429 gives the amount of $SO_3$ contained in the solution.

Example:

The sulphuric acid of 10 cubic centimeters of the dilute solution was precipitated with barium chloride and the weight of 3 determinations was found to be 2.0870 grams of barium sulphate.

Then:

$$2.0870 \times 0.3429 = 0.7156 \text{ gram of } SO_3$$
$$\text{and } 0.4003 : 0.7156 :: 10. : x = 17.877.$$

This shows that every 10 cubic centimeters of the dilute acid must be diluted to 17.877 cubic centimeters volume with distilled water. Consequently, 787.77 cubic centimeters of distilled water must be added to every liter.

**118. (Factory Acid).**—100 cubic centimeters of the above prepared normal acid diluted with 2,700 cubic centimeters of water gives an acid of convenient strength as trial acid for the sulphitation, etc.

One cubic centimeter then corresponds to 0.001 gram of $CaO$.

One hundred cubic centimeters of normal acid diluted with only 180 cubic centimeters of water gives an acid, 1 cubic centimeter of which corresponds to 0.01 gram of CaO.

**119. Soap Solution.**—50 grams of pure castile soap shavings are scraped and dissolved in 1 liter of alcohol (2 parts of absolute alcohol and 1 part of water).

The soap dissolves rather slowly and the solution should be shaken frequently. If any insoluble matter separates, it is filtered off and the filtrate kept in tightly-stoppered bottles. This solution is then standardized with a barium chloride or nitrate solution as described in Arts. 19 and 20.

# CHAPTER XVI.

## TABLES.

### TABLE I.

CORRECTIONS OF THE DEGREE BRIX FOR VARIATIONS IN TEMPERATURE FROM THE NORMAL: 17.5° C.

Deduct:

| Temp. Deg. C. | Degree Brix of the Solution. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0° | 5° | 10° | 15° | 20° | 25° | 30° | 35° | 40° | 50° | 60° | 70° | 75° |
| 0 | 0.17 | 0.30 | 0.41 | 0.52 | 0.62 | 0.72 | 0.82 | 0.92 | 0.98 | 1.11 | 1.22 | 1.25 | 1.29 |
| 5 | 0.23 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.65 | 0.72 | 0.75 | 0.80 | 0.88 | 0.91 | 0.94 |
| 10 | 0.20 | 0.26 | 0.29 | 0.33 | 0.36 | 0.39 | 0.42 | 0.45 | 0.48 | 0.50 | 0.54 | 0.58 | 0.61 |
| 11 | 0.18 | 0.23 | 0.26 | 0.28 | 0.31 | 0.34 | 0.36 | 0.39 | 0.41 | 0.43 | 0.47 | 0.50 | 0.53 |
| 12 | 0.16 | 0.20 | 0.22 | 0.24 | 0.26 | 0.29 | 0.31 | 0.33 | 0.34 | 0.36 | 0.40 | 0.42 | 0.46 |
| 13 | 0.14 | 0.18 | 0.19 | 0.21 | 0.22 | 0.24 | 0.26 | 0.27 | 0.28 | 0.29 | 0.33 | 0.35 | 0.39 |
| 14 | 0.12 | 0.15 | 0.16 | 0.17 | 0.18 | 0.19 | 0.21 | 0.22 | 0.22 | 0.23 | 0.26 | 0.28 | 0.32 |
| 15 | 0.09 | 0.11 | 0.12 | 0.14 | 0.14 | 0.15 | 0.16 | 0.17 | 0.16 | 0.17 | 0.19 | 0.21 | 0.25 |
| 16 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.10 | 0.11 | 0.12 | 0.12 | 0.12 | 0.14 | 0.16 | 0.18 |
| 17 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 |
| Add: | | | | | | | | | | | | | |
| 18 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 |
| 19 | 0.06 | 0.08 | 0.08 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.08 | 0.06 |
| 20 | 0.11 | 0.14 | 0.15 | 0.17 | 0.17 | 0.18 | 0.18 | 0.18 | 0.19 | 0.19 | 0.18 | 0.15 | 0.11 |
| 21 | 0.16 | 0.20 | 0.22 | 0.24 | 0.24 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.25 | 0.22 | 0.18 |
| 22 | 0.21 | 0.26 | 0.29 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.33 | 0.34 | 0.32 | 0.29 | 0.25 |
| 23 | 0.27 | 0.32 | 0.35 | 0.37 | 0.38 | 0.39 | 0.39 | 0.39 | 0.40 | 0.42 | 0.39 | 0.36 | 0.33 |
| 24 | 0.32 | 0.38 | 0.41 | 0.43 | 0.44 | 0.46 | 0.46 | 0.47 | 0.47 | 0.50 | 0.46 | 0.43 | 0.40 |
| 25 | 0.37 | 0.44 | 0.47 | 0.49 | 0.51 | 0.53 | 0.54 | 0.55 | 0.55 | 0.58 | 0.54 | 0.51 | 0.48 |
| 26 | 0.43 | 0.50 | 0.54 | 0.56 | 0.58 | 0.60 | 0.61 | 0.62 | 0.62 | 0.66 | 0.62 | 0.58 | 0.55 |
| 27 | 0.49 | 0.57 | 0.61 | 0.63 | 0.65 | 0.68 | 0.68 | 0.69 | 0.70 | 0.74 | 0.70 | 0.65 | 0.62 |
| 28 | 0.56 | 0.64 | 0.68 | 0.70 | 0.72 | 0.76 | 0.76 | 0.78 | 0.78 | 0.82 | 0.78 | 0.72 | 0.70 |
| 29 | 0.63 | 0.71 | 0.75 | 0.78 | 0.79 | 0.84 | 0.84 | 0.86 | 0.86 | 0.90 | 0.86 | 0.80 | 0.78 |
| 30 | 0.70 | 0.78 | 0.82 | 0.87 | 0.87 | 0.92 | 0.92 | 0.94 | 0.94 | 0.98 | 0.94 | 0.88 | 0.86 |
| 35 | 1.10 | 1.17 | 1.22 | 1.24 | 1.30 | 1.32 | 1.33 | 1.35 | 1.36 | 1.39 | 1.34 | 1.27 | 1.25 |
| 40 | 1.50 | 1.61 | 1.67 | 1.71 | 1.73 | 1.79 | 1.79 | 1.80 | 1.82 | 1.83 | 1.78 | 1.69 | 1.65 |
| 60 | — | 3.87 | 3.88 | 3.88 | 3.88 | 3.88 | 3.88 | 3.88 | 3.90 | 3.82 | 3.70 | 3.43 | 3.41 |
| 80 | — | — | 6.62 | 6.59 | 6.54 | 6.46 | 6.38 | 6.30 | 6.26 | 6.06 | 5.82 | 5.50 | 5.33 |
| 100 | — | — | 10.01 | 9.87 | 9.72 | 9.56 | 9.39 | 9.21 | 9.03 | 8.64 | 8.22 | 7.76 | 7.42 |

## TABLE II.

## COMPARISON OF THE DEGREE BRIX, THE SPECIFIC GRAVITY AND THE DEGREE BAUMÉ (CORRECTED).

(Temperature 17.5° C.)

(Already in the year of 1870, Gerlach gave absolute proof of the incorrectness of the formula used by Brix to calculate the "Baumé" from the specific gravity; these "old" degrees Baumé, however, are still in use.) The following table gives the "new" degrees Baumé; these having the preference of being correct.

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.00000 | 0.0 | 3.7 | 1.01451 | 2.1 | 7.4 | 1.02942 | 4.2 |
| 0.1 | 1.00038 | 0.1 | 3.8 | 1.01491 | 2.2 | 7.5 | 1.02983 | 4.2 |
| 0.2 | 1.00077 | 0.1 | 3.9 | 1.01531 | 2.2 | 7.6 | 1.03024 | 4.3 |
| 0.3 | 1.00116 | 0.2 | 4.0 | 1.01570 | 2.3 | 7.7 | 1.03064 | 4.4 |
| 0.4 | 1.00155 | 0.2 | 4.1 | 1.01610 | 2.3 | 7.8 | 1.03105 | 4.4 |
| 0.5 | 1.00193 | 0.3 | 4.2 | 1.01650 | 2.4 | 7.9 | 1.03146 | 4.5 |
| 0.6 | 1.00232 | 0.3 | 4.3 | 1.01690 | 2.4 | 8.0 | 1.03187 | 4.5 |
| 0.7 | 1.00271 | 0.4 | 4.4 | 1.01730 | 2.5 | 8.1 | 1.03228 | 4.6 |
| 0.8 | 1.00310 | 0.45 | 4.5 | 1.01770 | 2.55 | 8.2 | 1.03270 | 4.6 |
| 0.9 | 1.00349 | 0.5 | 4.6 | 1.01810 | 2.6 | 8.3 | 1.03311 | 4.7 |
| 1.0 | 1.00388 | 0.6 | 4.7 | 1.01850 | 2.7 | 8.4 | 1.03352 | 4.8 |
| 1.1 | 1.00427 | 0.6 | 4.8 | 1.01890 | 2.7 | 8.5 | 1.03393 | 4.8 |
| 1.2 | 1.00466 | 0.7 | 4.9 | 1.01930 | 2.8 | 8.6 | 1.03434 | 4.9 |
| 1.3 | 1.00505 | 0.7 | 5.0 | 1.01970 | 2.8 | 8.7 | 1.03475 | 4.9 |
| 1.4 | 1.00544 | 0.8 | 5.1 | 1.02010 | 2.9 | 8.8 | 1.03517 | 5.0 |
| 1.5 | 1.00583 | 0.85 | 5.2 | 1.02051 | 2.9 | 8.9 | 1.03558 | 5.0 |
| 1.6 | 1.00622 | 0.9 | 5.3 | 1.02091 | 3.0 | 9.0 | 1.03599 | 5.1 |
| 1.7 | 1.00662 | 1.0 | 5.4 | 1.02131 | 3.1 | 9.1 | 1.03640 | 5.2 |
| 1.8 | 1.00701 | 1.0 | 5.5 | 1.02171 | 3.1 | 9.2 | 1.03682 | 5.2 |
| 1.9 | 1.00740 | 1.1 | 5.6 | 1.02211 | 3.2 | 9.3 | 1.03723 | 5.3 |
| 2.0 | 1.00779 | 1.1 | 5.7 | 1.02252 | 3.2 | 9.4 | 1.03765 | 5.3 |
| 2.1 | 1.00818 | 1.2 | 5.8 | 1.02292 | 3.3 | 9.5 | 1.03806 | 5.4 |
| 2.2 | 1.00858 | 1.2 | 5.9 | 1.02333 | 3.3 | 9.6 | 1.03848 | 5.4 |
| 2.3 | 1.00897 | 1.3 | 6.0 | 1.02373 | 3.4 | 9.7 | 1.03889 | 5.5 |
| 2.4 | 1.00936 | 1.4 | 6.1 | 1.02413 | 3.5 | 9.8 | 1.03931 | 5.5 |
| 2.5 | 1.00976 | 1.4 | 6.2 | 1.02454 | 3.5 | 9.9 | 1.03972 | 5.6 |
| 2.6 | 1.01015 | 1.5 | 6.3 | 1.02494 | 3.6 | 10.0 | 1.04014 | 5.7 |
| 2.7 | 1.01055 | 1.5 | 6.4 | 1.02535 | 3.6 | 10.1 | 1.04055 | 5.7 |
| 2.8 | 1.01094 | 1.6 | 6.5 | 1.02575 | 3.7 | 10.2 | 1.04097 | 5.8 |
| 2.9 | 1.01134 | 1.6 | 6.6 | 1.02616 | 3.7 | 10.3 | 1.04139 | 5.8 |
| 3.0 | 1.01173 | 1.7 | 6.7 | 1.02657 | 3.8 | 10.4 | 1.04180 | 5.9 |
| 3.1 | 1.01213 | 1.8 | 6.8 | 1.02697 | 3.9 | 10.5 | 1.04222 | 5.9 |
| 3.2 | 1.01252 | 1.8 | 6.9 | 1.02738 | 3.9 | 10.6 | 1.04264 | 6.0 |
| 3.3 | 1.01292 | 1.9 | 7.0 | 1.02779 | 4.0 | 10.7 | 1.04306 | 6.1 |
| 3.4 | 1.01332 | 1.9 | 7.1 | 1.02819 | 4.0 | 10.8 | 1.04348 | 6.1 |
| 3.5 | 1.01371 | 1.9 | 7.2 | 1.02860 | 4.1 | 10.9 | 1.04390 | 6.2 |
| 3.6 | 1.01411 | 2.0 | 7.3 | 1.02901 | 4.1 | 11.0 | 1.04431 | 6.2 |

TABLE II—(*Continued*).

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 11.1 | 1.04473 | 6.3 | 15.9 | 1.06522 | 9.0 | 20.7 | 1.08643 | 11.7 |
| 11.2 | 1.04515 | 6.3 | 16.0 | 1.06566 | 9.0 | 20.8 | 1.08688 | 11.7 |
| 11.3 | 1.04557 | 6.4 | 16.1 | 1.06609 | 9.1 | 20.9 | 1.08733 | 11.8 |
| 11.4 | 1.04599 | 6.5 | 16.2 | 1.06653 | 9.2 | 21.0 | 1.08778 | 11.8 |
| 11.5 | 1.04641 | 6.5 | 16.3 | 1.06696 | 9.2 | 21.1 | 1.08824 | 11.9 |
| 11.6 | 1.04683 | 6.6 | 16.4 | 1.06740 | 9.3 | 21.2 | 1.08869 | 11.9 |
| 11.7 | 1.04726 | 6.6 | 16.5 | 1.06783 | 9.3 | 21.3 | 1.08914 | 12.0 |
| 11.8 | 1.04768 | 6.7 | 16.6 | 1.06827 | 9.4 | 21.4 | 1.08959 | 12.0 |
| 11.9 | 1.04810 | 6.7 | 16.7 | 1.06871 | 9.4 | 21.5 | 1.09004 | 12.1 |
| 12.0 | 1.04852 | 6.8 | 16.8 | 1.06914 | 9.5 | 21.6 | 1.09049 | 12.1 |
| 12.1 | 1.04894 | 6.8 | 16.9 | 1.06958 | 9.5 | 21.7 | 1.09095 | 12.2 |
| 12.2 | 1.04937 | 6.9 | 17.0 | 1.07002 | 9.6 | 21.8 | 1.09140 | 12.3 |
| 12.3 | 1.04979 | 7.0 | 17.1 | 1.07046 | 9.7 | 21.9 | 1.09185 | 12.3 |
| 12.4 | 1.05021 | 7.0 | 17.2 | 1.07090 | 9.7 | 22.0 | 1.09231 | 12.4 |
| 12.5 | 1.05064 | 7.1 | 17.3 | 1.07133 | 9.8 | 22.1 | 1.09276 | 12.5 |
| 12.6 | 1.05106 | 7.1 | 17.4 | 1.07177 | 9.8 | 22.2 | 1.09321 | 12.5 |
| 12.7 | 1.05149 | 7.2 | 17.5 | 1.07221 | 9.9 | 22.3 | 1.09367 | 12.6 |
| 12.8 | 1.05191 | 7.2 | 17.6 | 1.07265 | 9.9 | 22.4 | 1.09412 | 12.6 |
| 12.9 | 1.05233 | 7.3 | 17.7 | 1.07309 | 10.0 | 22.5 | 1.09458 | 12.7 |
| 13.0 | 1.05276 | 7.4 | 17.8 | 1.07353 | 10.0 | 22.6 | 1.09503 | 12.7 |
| 13.1 | 1.05318 | 7.4 | 17.9 | 1.07417 | 10.1 | 22.7 | 1.09549 | 12.8 |
| 13.2 | 1.05361 | 7.5 | 18.0 | 1.07441 | 10.1 | 22.8 | 1.09595 | 12.8 |
| 13.3 | 1.05404 | 7.5 | 18.1 | 1.07505 | 10.2 | 22.9 | 1.09640 | 12.9 |
| 13.4 | 1.05446 | 7.6 | 18.2 | 1.07530 | 10.3 | 23.0 | 1.09686 | 13.0 |
| 13.5 | 1.05489 | 7.6 | 18.3 | 1.07574 | 10.3 | 23.1 | 1.09732 | 13.0 |
| 13.6 | 1.05532 | 7.7 | 18.4 | 1.07618 | 10.4 | 23.2 | 1.09777 | 13.1 |
| 13.7 | 1.05574 | 7.8 | 18.5 | 1.07662 | 10.4 | 23.3 | 1.09823 | 13.1 |
| 13.8 | 1.05617 | 7.8 | 18.6 | 1.07705 | 10.5 | 23.4 | 1.09869 | 13.2 |
| 13.9 | 1.05660 | 7.9 | 18.7 | 1.07751 | 10.5 | 23.5 | 1.09915 | 13.2 |
| 14.0 | 1.05703 | 7.9 | 18.8 | 1.07795 | 10.6 | 23.6 | 1.09961 | 13.3 |
| 14.1 | 1.05746 | 8.0 | 18.9 | 1.07839 | 10.6 | 23.7 | 1.10007 | 13.3 |
| 14.2 | 1.05789 | 8.0 | 19.0 | 1.07884 | 10.7 | 23.8 | 1.10053 | 13.4 |
| 14.3 | 1.05831 | 8.1 | 19.1 | 1.07928 | 10.8 | 23.9 | 1.10099 | 13.5 |
| 14.4 | 1.05874 | 8.1 | 19.2 | 1.07973 | 10.8 | 24.0 | 1.10145 | 13.5 |
| 14.5 | 1.05917 | 8.2 | 19.3 | 1.08017 | 10.9 | 24.1 | 1.10191 | 13.6 |
| 14.6 | 1.05960 | 8.3 | 19.4 | 1.08062 | 10.9 | 24.2 | 1.10237 | 13.6 |
| 14.7 | 1.06003 | 8.3 | 19.5 | 1.08106 | 11.0 | 24.3 | 1.10283 | 13.7 |
| 14.8 | 1.06047 | 8.4 | 19.6 | 1.08151 | 11.1 | 24.4 | 1.10329 | 13.7 |
| 14.9 | 1.06090 | 8.4 | 19.7 | 1.08196 | 11.1 | 24.5 | 1.10375 | 13.8 |
| 15.0 | 1.06133 | 8.5 | 19.8 | 1.08240 | 11.2 | 24.6 | 1.10421 | 13.8 |
| 15.1 | 1.06176 | 8.5 | 19.9 | 1.08285 | 11.2 | 24.7 | 1.10468 | 13.9 |
| 15.2 | 1.06219 | 8.6 | 20.0 | 1.08329 | 11.3 | 24.8 | 1.10514 | 14.0 |
| 15.3 | 1.06262 | 8.6 | 20.1 | 1.08374 | 11.3 | 24.9 | 1.10560 | 14.0 |
| 15.4 | 1.06306 | 8.7 | 20.2 | 1.08419 | 11.4 | 25.0 | 1.10607 | 14.1 |
| 15.5 | 1.06349 | 8.8 | 20.3 | 1.08464 | 11.5 | 25.1 | 1.10653 | 14.1 |
| 15.6 | 1.06392 | 8.8 | 20.4 | 1.08509 | 11.5 | 25.2 | 1.10700 | 14.2 |
| 15.7 | 1.06436 | 8.9 | 20.5 | 1.08553 | 11.6 | 25.3 | 1.10746 | 14.2 |
| 15.8 | 1.06479 | 8.9 | 20.6 | 1.08599 | 11.6 | 25.4 | 1.10793 | 14.3 |

## TABLE II—(*Continued*).

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 25.5 | 1.10839 | 14.3 | 30.3 | 1.13111 | 17.0 | 35.1 | 1.15461 | 19.7 |
| 25.6 | 1.10886 | 14.4 | 30.4 | 1.13159 | 17.1 | 35.2 | 1.15511 | 19.7 |
| 25.7 | 1.10932 | 14.5 | 30.5 | 1.13207 | 17.1 | 35.3 | 1.15561 | 19.8 |
| 25.8 | 1.10979 | 14.5 | 30.6 | 1.13255 | 17.2 | 35.4 | 1.15611 | 19.8 |
| 25.9 | 1.11026 | 14.6 | 30.7 | 1.13304 | 17.2 | 35.5 | 1.15661 | 19.9 |
| 26.0 | 1.11072 | 14.6 | 30.8 | 1.13352 | 17.3 | 35.6 | 1.15710 | 19.9 |
| 26.1 | 1.11119 | 14.7 | 30.9 | 1.13400 | 17.3 | 35.7 | 1.15760 | 20.0 |
| 26.2 | 1.11166 | 14.7 | 31.0 | 1.13449 | 17.4 | 35.8 | 1.15810 | 20.0 |
| 26.3 | 1.11213 | 14.8 | 31.1 | 1.13497 | 17.5 | 35.9 | 1.15861 | 20.1 |
| 26.4 | 1.11259 | 14.9 | 31.2 | 1.13545 | 17.5 | 36.0 | 1.15917 | 20.1 |
| 26.5 | 1.11306 | 14.9 | 31.3 | 1.13594 | 17.6 | 36.1 | 1.15961 | 20.2 |
| 26.6 | 1.11353 | 15.0 | 31.4 | 1.13642 | 17.6 | 36.2 | 1.16011 | 20.3 |
| 26.7 | 1.11400 | 15.0 | 31.5 | 1.13691 | 17.7 | 36.3 | 1.16061 | 20.3 |
| 26.8 | 1.11447 | 15.1 | 31.6 | 1.13740 | 17.7 | 36.4 | 1.16111 | 20.4 |
| 26.9 | 1.11494 | 15.1 | 31.7 | 1.13788 | 17.8 | 36.5 | 1.16162 | 20.4 |
| 27.0 | 1.11541 | 15.2 | 31.8 | 1.13837 | 17.8 | 36.6 | 1.16212 | 20.5 |
| 27.1 | 1.11588 | 15.2 | 31.9 | 1.13885 | 17.9 | 36.7 | 1.16262 | 20.5 |
| 27.2 | 1.11635 | 15.3 | 32.0 | 1.13934 | 18.0 | 36.8 | 1.16313 | 20.6 |
| 27.3 | 1.11682 | 15.3 | 32.1 | 1.13983 | 18.0 | 36.9 | 1.16363 | 20.6 |
| 27.4 | 1.11729 | 15.4 | 32.2 | 1.14032 | 18.0 | 37.0 | 1.16413 | 20.7 |
| 27.5 | 1.11776 | 15.5 | 32.3 | 1.14081 | 18.1 | 37.1 | 1.16464 | 20.7 |
| 27.6 | 1.11824 | 15.5 | 32.4 | 1.14129 | 18.2 | 37.2 | 1.16514 | 20.8 |
| 27.7 | 1.11871 | 15.6 | 32.5 | 1.14178 | 18.2 | 37.3 | 1.16565 | 20.9 |
| 27.8 | 1.11918 | 15.6 | 32.6 | 1.14227 | 18.3 | 37.4 | 1.16616 | 20.9 |
| 27.9 | 1.11965 | 15.7 | 32.7 | 1.14276 | 18.3 | 37.5 | 1.16666 | 21.0 |
| 28.0 | 1.12013 | 15.7 | 32.8 | 1.14325 | 18.4 | 37.6 | 1.16717 | 21.0 |
| 28.1 | 1.12060 | 15.8 | 32.9 | 1.14374 | 18.4 | 37.7 | 1.16768 | 21.1 |
| 28.2 | 1.12107 | 15.8 | 33.0 | 1.14423 | 18.5 | 37.8 | 1.16818 | 21.1 |
| 28.3 | 1.12155 | 15.9 | 33.1 | 1.14472 | 18.6 | 37.9 | 1.16869 | 21.2 |
| 28.4 | 1.12202 | 16.0 | 33.2 | 1.14521 | 18.6 | 38.0 | 1.16920 | 21.2 |
| 28.5 | 1.12250 | 16.0 | 33.3 | 1.14570 | 18.7 | 38.1 | 1.16971 | 21.3 |
| 28.6 | 1.12297 | 16.1 | 33.4 | 1.14620 | 18.7 | 38.2 | 1.17022 | 21.4 |
| 28.7 | 1.12345 | 16.1 | 33.5 | 1.14669 | 18.8 | 38.3 | 1.17072 | 21.4 |
| 28.8 | 1.12393 | 16.2 | 33.6 | 1.14718 | 18.8 | 38.4 | 1.17123 | 21.5 |
| 28.9 | 1.12440 | 16.2 | 33.7 | 1.14767 | 18.9 | 38.5 | 1.17174 | 21.5 |
| 29.0 | 1.12488 | 16.3 | 33.8 | 1.14817 | 18.9 | 38.6 | 1.17225 | 21.6 |
| 29.1 | 1.12536 | 16.3 | 33.9 | 1.14866 | 19.0 | 38.7 | 1.17276 | 21.6 |
| 29.2 | 1.12583 | 16.4 | 34.0 | 1.14915 | 19.1 | 38.8 | 1.17327 | 21.7 |
| 29.3 | 1.12631 | 16.5 | 34.1 | 1.14965 | 19.1 | 38.9 | 1.17379 | 21.7 |
| 29.4 | 1.12679 | 16.5 | 34.2 | 1.15014 | 19.2 | 39.0 | 1.17430 | 21.8 |
| 29.5 | 1.12727 | 16.6 | 34.3 | 1.15064 | 19.2 | 39.1 | 1.17481 | 21.8 |
| 29.6 | 1.12775 | 16.6 | 34.4 | 1.15113 | 19.3 | 39.2 | 1.17532 | 21.9 |
| 29.7 | 1.12823 | 16.7 | 34.5 | 1.15163 | 19.3 | 39.3 | 1.17583 | 21.9 |
| 29.8 | 1.12871 | 16.7 | 34.6 | 1.15213 | 19.4 | 39.4 | 1.17635 | 22.0 |
| 29.9 | 1.12919 | 16.8 | 34.7 | 1.15262 | 19.4 | 39.5 | 1.17686 | 22.1 |
| 30.0 | 1.12967 | 16.8 | 34.8 | 1.15312 | 19.5 | 39.6 | 1.17737 | 22.1 |
| 30.1 | 1.13015 | 16.9 | 34.9 | 1.15362 | 19.5 | 39.7 | 1.17789 | 22.2 |
| 30.2 | 1.13063 | 17.0 | 35.0 | 1.15411 | 19.6 | 39.8 | 1.17840 | 22.2 |

TABLE II—(*Continued*).

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 39.9 | 1.17892 | 22.3 | 44.7 | 1.20405 | 24.9 | 49.5 | 1.23003 | 27.4 |
| 40.0 | 1.17943 | 22.3 | 44.8 | 1.20458 | 24.9 | 49.6 | 1.23058 | 27.5 |
| 40.1 | 1.17995 | 22.4 | 44.9 | 1.20512 | 25.0 | 49.7 | 1.23113 | 27.6 |
| 40.2 | 1.18046 | 22.4 | 45.0 | 1.20565 | 25.0 | 49.8 | 1.23168 | 27.6 |
| 40.3 | 1.18098 | 22.5 | 45.1 | 1.20618 | 25.1 | 49.9 | 1.23223 | 27.7 |
| 40.4 | 1.18150 | 22.5 | 45.2 | 1.20672 | 25.1 | 50.0 | 1.23278 | 27.7 |
| 40.5 | 1.18201 | 22.6 | 45.3 | 1.20725 | 25.2 | 50.1 | 1.23334 | 27.8 |
| 40.6 | 1.18253 | 22.6 | 45.4 | 1.20779 | 25.2 | 50.2 | 1.23389 | 27.8 |
| 40.7 | 1.18305 | 22.7 | 45.5 | 1.20832 | 25.3 | 50.3 | 1.23444 | 27.9 |
| 40.8 | 1.18357 | 22.8 | 45.6 | 1.20886 | 25.4 | 50.4 | 1.23499 | 27.9 |
| 40.9 | 1.18408 | 22.8 | 45.7 | 1.20939 | 25.4 | 50.5 | 1.23555 | 28.0 |
| 41.0 | 1.18460 | 22.9 | 45.8 | 1.20993 | 25.5 | 50.6 | 1.23610 | 28.0 |
| 41.1 | 1.18512 | 22.9 | 45.9 | 1.21046 | 25.5 | 50.7 | 1.23666 | 28.1 |
| 41.2 | 1.18564 | 23.0 | 46.0 | 1.21100 | 25.6 | 50.8 | 1.23721 | 28.1 |
| 41.3 | 1.18616 | 23.0 | 46.1 | 1.21154 | 25.6 | 50.9 | 1.23777 | 28.2 |
| 41.4 | 1.18668 | 23.1 | 46.2 | 1.21208 | 25.7 | 51.0 | 1.23832 | 28.2 |
| 41.5 | 1.18720 | 23.1 | 46.3 | 1.21261 | 25.7 | 51.1 | 1.23888 | 28.3 |
| 41.6 | 1.18772 | 23.2 | 46.4 | 1.21315 | 25.8 | 51.2 | 1.23943 | 28.4 |
| 41.7 | 1.18824 | 23.3 | 46.5 | 1.21369 | 25.8 | 51.3 | 1.23999 | 28.4 |
| 41.8 | 1.18877 | 23.3 | 46.6 | 1.21423 | 25.9 | 51.4 | 1.24055 | 28.5 |
| 41.9 | 1.18929 | 23.4 | 46.7 | 1.21477 | 26.0 | 51.5 | 1.24111 | 28.5 |
| 42.0 | 1.18981 | 23.4 | 46.8 | 1.21531 | 26.0 | 51.6 | 1.24166 | 28.6 |
| 42.1 | 1.19033 | 23.5 | 46.9 | 1.21585 | 26.1 | 51.7 | 1.24222 | 28.6 |
| 42.2 | 1.19086 | 23.5 | 47.0 | 1.21639 | 26.1 | 51.8 | 1.24278 | 28.7 |
| 42.3 | 1.19138 | 23.6 | 47.1 | 1.21693 | 26.2 | 51.9 | 1.24334 | 28.7 |
| 42.4 | 1.19190 | 23.6 | 47.2 | 1.21747 | 26.2 | 52.0 | 1.24390 | 28.8 |
| 42.5 | 1.19243 | 23.7 | 47.3 | 1.21802 | 26.3 | 52.1 | 1.24446 | 28.8 |
| 42.6 | 1.19295 | 23.7 | 47.4 | 1.21856 | 26.3 | 52.2 | 1.24502 | 28.9 |
| 42.7 | 1.19348 | 23.8 | 47.5 | 1.21910 | 26.4 | 52.3 | 1.24558 | 28.9 |
| 42.8 | 1.19400 | 23.8 | 47.6 | 1.21946 | 26.4 | 52.4 | 1.24614 | 29.0 |
| 42.9 | 1.19453 | 23.9 | 47.7 | 1.22019 | 26.5 | 52.5 | 1.24670 | 29.0 |
| 43.0 | 1.19505 | 24.0 | 47.8 | 1.22073 | 26.5 | 52.6 | 1.24726 | 29.1 |
| 43.1 | 1.19558 | 24.0 | 47.9 | 1.22127 | 26.6 | 52.7 | 1.24782 | 29.2 |
| 43.2 | 1.19611 | 24.1 | 48.0 | 1.22182 | 26.6 | 52.8 | 1.24839 | 29.2 |
| 43.3 | 1.19663 | 24.1 | 48.1 | 1.22236 | 26.7 | 52.9 | 1.24895 | 29.2 |
| 43.4 | 1.19716 | 24.2 | 48.2 | 1.22291 | 26.8 | 53.0 | 1.24951 | 29.3 |
| 43.5 | 1.19769 | 24.2 | 48.3 | 1.22345 | 26.8 | 53.1 | 1.25008 | 29.4 |
| 43.6 | 1.19822 | 24.3 | 48.4 | 1.22400 | 26.9 | 53.2 | 1.25064 | 29.4 |
| 43.7 | 1.19875 | 24.3 | 48.5 | 1.22455 | 26.9 | 53.3 | 1.25120 | 29.5 |
| 43.8 | 1.19927 | 24.4 | 48.6 | 1.22509 | 27.0 | 53.4 | 1.25177 | 29.5 |
| 43.9 | 1.19980 | 24.4 | 48.7 | 1.22564 | 27.0 | 53.5 | 1.25233 | 29.6 |
| 44.0 | 1.20033 | 24.5 | 48.8 | 1.22619 | 27.1 | 53.6 | 1.25290 | 29.6 |
| 44.1 | 1.20086 | 24.6 | 48.9 | 1.22673 | 27.1 | 53.7 | 1.25347 | 29.7 |
| 44.2 | 1.20139 | 24.6 | 49.0 | 1.22728 | 27.2 | 53.8 | 1.25403 | 29.7 |
| 44.3 | 1.20192 | 24.7 | 49.1 | 1.22783 | 27.2 | 53.9 | 1.25460 | 29.8 |
| 44.4 | 1.20245 | 24.7 | 49.2 | 1.22838 | 27.3 | 54.0 | 1.25517 | 29.8 |
| 44.5 | 1.20299 | 24.8 | 49.3 | 1.22893 | 27.3 | 54.1 | 1.25573 | 29.9 |
| 44.6 | 1.20352 | 24.8 | 49.4 | 1.22948 | 27.4 | 54.2 | 1.25630 | 29.9 |

## TABLE II—(*Continued*).

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 54.3 | 1.25687 | 30.0 | 59.1 | 1.28459 | 32.5 | 63.9 | 1.31320 | 35.0 |
| 54.4 | 1.25744 | 30.1 | 59.2 | 1.28518 | 32.6 | 64.0 | 1.31381 | 35.1 |
| 54.5 | 1.25801 | 30.1 | 59.3 | 1.28576 | 32.6 | 64.1 | 1.31442 | 35.1 |
| 54.6 | 1.25857 | 30.2 | 59.4 | 1.28635 | 32.7 | 64.2 | 1.31502 | 35.2 |
| 54.7 | 1.25914 | 30.2 | 59.5 | 1.28694 | 32.7 | 64.3 | 1.31563 | 35.2 |
| 54.8 | 1.25971 | 30.3 | 59.6 | 1.28753 | 32.8 | 64.4 | 1.31624 | 35.3 |
| 54.9 | 1.26028 | 30.3 | 59.7 | 1.28812 | 32.8 | 64.5 | 1.31684 | 35.3 |
| 55.0 | 1.26086 | 30.4 | 59.8 | 1.28871 | 32.9 | 64.6 | 1.31745 | 35.4 |
| 55.1 | 1.26143 | 30.4 | 59.9 | 1.28930 | 32.9 | 64.7 | 1.31806 | 35.4 |
| 55.2 | 1.26200 | 30.5 | 60.0 | 1.28989 | 33.0 | 64.8 | 1.31867 | 35.5 |
| 55.3 | 1.26257 | 30.5 | 60.1 | 1.29048 | 33.0 | 64.9 | 1.31928 | 35.5 |
| 55.4 | 1.26314 | 30.6 | 60.2 | 1.29107 | 33.1 | 65.0 | 1.31989 | 35.6 |
| 55.5 | 1.26372 | 30.6 | 60.3 | 1.29166 | 33.1 | 65.1 | 1.32050 | 35.6 |
| 55.6 | 1.26429 | 30.7 | 60.4 | 1.29225 | 33.2 | 65.2 | 1.32111 | 35.7 |
| 55.7 | 1.26486 | 30.7 | 60.5 | 1.29284 | 33.2 | 65.3 | 1.32172 | 35.7 |
| 55.8 | 1.26544 | 30.8 | 60.6 | 1.29343 | 33.3 | 65.4 | 1.32233 | 35.8 |
| 55.9 | 1.26601 | 30.8 | 60.7 | 1.29403 | 33.4 | 65.5 | 1.32294 | 35.8 |
| 56.0 | 1.26658 | 30.9 | 60.8 | 1.29462 | 33.4 | 65.6 | 1.32355 | 35.9 |
| 56.1 | 1.26716 | 30.9 | 60.9 | 1.29521 | 33.5 | 65.7 | 1.32417 | 35.9 |
| 56.2 | 1.26773 | 31.0 | 61.0 | 1.29581 | 33.5 | 65.8 | 1.32478 | 36.0 |
| 56.3 | 1.26831 | 31.1 | 61.1 | 1.29640 | 33.6 | 65.9 | 1.32539 | 36.0 |
| 56.4 | 1.26889 | 31.1 | 61.2 | 1.29700 | 73.6 | 66.0 | 1.32601 | 36.1 |
| 56.5 | 1.26946 | 31.2 | 61.3 | 2.29759 | 33.7 | 66.1 | 2 32662 | 36.1 |
| 56.6 | 1.27004 | 31.2 | 61.4 | 1.29819 | 33.7 | 66.2 | 1.32724 | 36.2 |
| 56.7 | 1.27062 | 31.3 | 61.5 | 1.29878 | 33.8 | 66.3 | 1.32785 | 36.2 |
| 56.8 | 1.27120 | 31.3 | 61.6 | 1.29938 | 33.8 | 66.4 | 1.32847 | 36.3 |
| 56.9 | 1.27177 | 31.4 | 61.7 | 1.29998 | 33.9 | 66.5 | 1.32908 | 36.3 |
| 57.0 | 1.27235 | 31.4 | 61.8 | 1.30057 | 33.9 | 66.6 | 1.32970 | 36.4 |
| 57.1 | 1.27293 | 31.5 | 61.9 | 1.30117 | 34.0 | 66.7 | 1.33031 | 36.4 |
| 57.2 | 1.27351 | 31.5 | 62.0 | 1.30177 | 34.0 | 66.8 | 1.33093 | 36.5 |
| 57.3 | 1.27409 | 31.6 | 62.1 | 1.30237 | 34.1 | 66.9 | 1.33155 | 36.5 |
| 57.4 | 1.27464 | 31.6 | 62.2 | 1.30297 | 34.1 | 67.0 | 1.33217 | 36.6 |
| 57.5 | 1.27525 | 31.7 | 62.3 | 1.30356 | 34.2 | 67.1 | 1.33278 | 36.6 |
| 57.6 | 1.27583 | 31.7 | 62.4 | 1.30416 | 34.2 | 67.2 | 1.33340 | 36.7 |
| 57.7 | 1.27641 | 31.8 | 62.5 | 1.30476 | 34.3 | 67.3 | 1.33402 | 36.8 |
| 57.8 | 1.27699 | 31.8 | 62.6 | 1.30536 | 34.3 | 67.4 | 1.33464 | 36.8 |
| 57.9 | 1.27758 | 31.9 | 62.7 | 1.30596 | 34.4 | 67.5 | 1.33526 | 36.9 |
| 58.0 | 1.27816 | 31.9 | 62.8 | 1.30657 | 34.4 | 67.6 | 1.33588 | 36.9 |
| 58.1 | 1.27874 | 32.0 | 62 9 | 1.30717 | 34.5 | 67.7 | 1.33650 | 37.0 |
| 58.2 | 1.27932 | 32.0 | 63.0 | 1.30777 | 34.5 | 67.8 | 1.33712 | 37.0 |
| 58.3 | 1.27991 | 32.1 | 63.1 | 1.30837 | 34.6 | 67.9 | 1.33774 | 37.0 |
| 58.4 | 1.28049 | 32.2 | 63.2 | 1.30897 | 34.6 | 68.0 | 1.33836 | 37.1 |
| 58.5 | 1.28107 | 32.2 | 63.3 | 1.30958 | 34.7 | 68.1 | 1.33899 | 37.1 |
| 58.6 | 1.28166 | 32.3 | 63.4 | 1.31018 | 34.7 | 68.2 | 1.33961 | 37.2 |
| 58.7 | 1.28224 | 32.3 | 63.5 | 1.31078 | 34.8 | 68.3 | 1.34023 | 37.3 |
| 58.8 | 1.28283 | 32.4 | 63.6 | 1.31139 | 34.9 | 68.4 | 1.34085 | 37.3 |
| 58.9 | 1.28342 | 32.4 | 63.7 | 1.31199 | 34.9 | 68.5 | 1.34148 | 37.4 |
| 59.0 | 1.28400 | 32.5 | 63.8 | 1.31260 | 35.0 | 68.6 | 1.34210 | 37.4 |
|  |  |  |  |  |  | 68.7 | 1.34273 | 37.5 |

TABLE II—(*Continued*).

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 68.8 | 1.34335 | 37.5 | 73.6 | 1.37381 | 39.9 | 78.4 | 1.40520 | 42.3 |
| 68.9 | 1.34398 | 37.6 | 73.7 | 1.37446 | 40.0 | 78.5 | 1.40586 | 42.4 |
| 69.0 | 1.34460 | 37.6 | 73.8 | 1.37510 | 40.0 | 78.6 | 1.40652 | 42.4 |
| 69.1 | 1.34523 | 37.7 | 73.9 | 1.37575 | 40.1 | 78.7 | 1.40719 | 42.5 |
| 69.2 | 1.34585 | 37.7 | 74.0 | 1.37639 | 40.1 | 78.8 | 1.40785 | 42.5 |
| 69.3 | 1.34648 | 37.8 | 74.1 | 1.37704 | 40.2 | 78.9 | 1.40852 | 42.6 |
| 69.4 | 1.34711 | 37.8 | 74.2 | 1.37768 | 40.2 | 79.0 | 1.40918 | 42.6 |
| 69.5 | 1.34774 | 37.9 | 74.3 | 1.37833 | 40.3 | 79.1 | 1.40985 | 42.7 |
| 69.6 | 1.34836 | 37.9 | 74.4 | 1.37898 | 40.3 | 79.2 | 1.41052 | 42.7 |
| 69.7 | 1.34899 | 38.0 | 74.5 | 1.37962 | 40.4 | 79.3 | 1.41118 | 42.8 |
| 69.8 | 1.34962 | 38.0 | 74.6 | 1.38027 | 40.4 | 79.4 | 1.41185 | 42.8 |
| 69.9 | 1.35025 | 38.1 | 74.7 | 1.38092 | 40.5 | 79.5 | 1.41252 | 42.9 |
| 70.0 | 1.35088 | 38.1 | 74.8 | 1.38157 | 40.5 | 79.6 | 1.41318 | 42.9 |
| 70.1 | 1.35151 | 38.2 | 74.9 | 1.38222 | 40.6 | 79.7 | 1.41385 | 43.0 |
| 70.2 | 1.35214 | 38.2 | 75.0 | 1.38287 | 40.6 | 79.8 | 1.41452 | 43.0 |
| 70.3 | 1.35277 | 38.3 | 75.1 | 1.38352 | 40.7 | 79.9 | 1.41519 | 43.1 |
| 70.4 | 1.35340 | 38.3 | 75.2 | 1.38417 | 40.7 | 80.0 | 1.41586 | 43.1 |
| 70.5 | 1.35403 | 38.4 | 75.3 | 1.38482 | 40.8 | 80.1 | 1.41653 | 43.2 |
| 70.6 | 1.35466 | 38.4 | 75.4 | 1.38547 | 40.8 | 80.2 | 1.41720 | 43.2 |
| 70.7 | 1.35530 | 38.5 | 75.5 | 1.38612 | 40.9 | 80.3 | 1.41787 | 43.2 |
| 70.8 | 1.35593 | 38.5 | 75.6 | 1.38677 | 40.9 | 80.4 | 1.41854 | 43.3 |
| 70.9 | 1.35656 | 38.6 | 75.7 | 1.38743 | 41.0 | 80.5 | 1.41921 | 43.3 |
| 71.0 | 1.35720 | 38.6 | 75.8 | 1.38808 | 41.0 | 80.6 | 1.41989 | 43.4 |
| 71.1 | 1.35783 | 38.7 | 75.9 | 1.38873 | 41.1 | 80.7 | 1.42056 | 43.5 |
| 71.2 | 1.35847 | 38.7 | 76.0 | 1.38939 | 41.1 | 80.8 | 1.42123 | 43.5 |
| 71.3 | 1.35910 | 38.8 | 76.1 | 1.39004 | 41.2 | 80.9 | 1.42190 | 43.6 |
| 71.4 | 1.35974 | 38.8 | 76.2 | 1.39070 | 41.2 | 81.0 | 1.42258 | 43.6 |
| 71.5 | 1.36037 | 38.9 | 76.3 | 1.39135 | 41.3 | 81.1 | 1.42325 | 43.7 |
| 71.6 | 1.36101 | 38.9 | 76.4 | 1.39201 | 41.3 | 81.2 | 1.42393 | 43.7 |
| 71.7 | 1.36164 | 39.0 | 76.5 | 1.39266 | 41.4 | 81.3 | 1.42460 | 43.7 |
| 71.8 | 1.36228 | 39.0 | 76.6 | 1.39332 | 41.4 | 81.4 | 1.42528 | 43.8 |
| 71.9 | 1.36292 | 39.1 | 76.7 | 1.39397 | 41.5 | 81.5 | 1.42595 | 43.8 |
| 72.0 | 1.36355 | 39.1 | 76.8 | 1.39463 | 41.5 | 81.6 | 1.42663 | 43.9 |
| 72.1 | 1.36419 | 39.2 | 76.9 | 1.39529 | 41.6 | 81.7 | 1.42731 | 43.9 |
| 72.2 | 1.36483 | 39.2 | 77.0 | 1.39595 | 41.6 | 81.8 | 1.42798 | 44.0 |
| 72.3 | 1.36547 | 39.3 | 77.1 | 1.39660 | 41.7 | 81.9 | 1.42866 | 44.0 |
| 72.4 | 1.36611 | 39.3 | 77.2 | 1.39726 | 41.7 | 82.0 | 1.42934 | 44.1 |
| 72.5 | 1.36675 | 39.4 | 77.3 | 1.39792 | 41.8 | 82.1 | 1.43002 | 44.1 |
| 72.6 | 1.36739 | 39.4 | 77.4 | 1.39858 | 41.8 | 82.2 | 1.43070 | 44.2 |
| 72.7 | 1.36803 | 39.5 | 77.5 | 1.39924 | 41.9 | 82.3 | 1.43137 | 44.2 |
| 72.8 | 1.36867 | 39.5 | 77.6 | 1.39990 | 41.9 | 82.4 | 1.43205 | 44.3 |
| 72.9 | 1.36931 | 39.6 | 77.7 | 1.40056 | 42.0 | 82.5 | 1.43273 | 44.3 |
| 73.0 | 1.36995 | 39.6 | 77.8 | 1.40122 | 42.0 | 82.6 | 1.43341 | 44.4 |
| 73.1 | 1.37059 | 39.7 | 77.9 | 1.40188 | 42.1 | 82.7 | 1.43409 | 44.4 |
| 73.2 | 1.37124 | 39.7 | 78.0 | 1.40254 | 42.1 | 82.8 | 1.43478 | 44.5 |
| 73.3 | 1.37188 | 39.8 | 78.1 | 1.40321 | 42.2 | 82.9 | 1.43546 | 44.5 |
| 73.4 | 1.37252 | 39.8 | 78.2 | 1.40387 | 42.2 | 83.0 | 1.43614 | 44.6 |
| 73.5 | 1.37317 | 39.9 | 78.3 | 1.40453 | 42.3 | 83.1 | 1.43682 | 44.6 |

TABLE II—(*Continued*).

| Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) | Brix | Specific gravity | Baumé ("new" corrected) |
|---|---|---|---|---|---|---|---|---|
| 83.2 | 1.43750 | 44.7 | 85.5 | 1.45331 | 45.8 | 87.8 | 1.46934 | 46.9 |
| 83.3 | 1.43819 | 44.7 | 85.6 | 1.45401 | 45.8 | 87.9 | 1.47004 | 46.9 |
| 83.4 | 1.43887 | 44.8 | 85.7 | 1.45470 | 45.9 | 88.0 | 1.47074 | 47.0 |
| 83.5 | 1.43955 | 44.8 | 85.8 | 1.45539 | 45.9 | 88.1 | 1.47145 | 47.0 |
| 83.6 | 1.44024 | 44.9 | 85.9 | 1.45609 | 46.0 | 88.2 | 1.47215 | 47.1 |
| 83.7 | 1.44092 | 44.9 | 86.0 | 1.45678 | 46.0 | 88.3 | 1.47285 | 47.1 |
| 83.8 | 1.44161 | 45.0 | 86.1 | 1.45748 | 46.1 | 88.4 | 1.47356 | 47.2 |
| 83.9 | 1.44229 | 45.0 | 86.2 | 1.45817 | 46.1 | 88.5 | 1.47426 | 47.2 |
| 84.0 | 1.44298 | 45.1 | 86.3 | 1.45887 | 46.2 | 88.6 | 1.47496 | 47.3 |
| 84.1 | 1.44367 | 45.1 | 86.4 | 1.45956 | 46 2 | 88.7 | 1.47567 | 47.3 |
| 84.2 | 1.44435 | 45.2 | 86.5 | 1.46026 | 46.3 | 88.8 | 1.47637 | 47.4 |
| 84.3 | 1.44504 | 45.2 | 86.6 | 1.46095 | 46.3 | 88.9 | 1.47708 | 47.4 |
| 84.4 | 1.44573 | 45.3 | 86.7 | 1.46165 | 46.4 | 89.0 | 1.47778 | 47.5 |
| 84.5 | 1.44641 | 45.3 | 86.8 | 1.46235 | 46.4 | 89.1 | 1.47849 | 47.5 |
| 84.6 | 1.44710 | 45.4 | 86.9 | 1.46304 | 46.5 | 89.2 | 1.47920 | 47.6 |
| 84.7 | 1.44779 | 45.4 | 87.0 | 1.46374 | 46.5 | 89.3 | 1.47991 | 47.6 |
| 84.8 | 1.44848 | 45.4 | 87.1 | 1.46444 | 46.6 | 89.4 | 1.48061 | 47.6 |
| 84.9 | 1.44917 | 45.5 | 87.2 | 1.46514 | 46.6 | 89.5 | 1.48132 | 47.7 |
| 85.0 | 1.44986 | 45.5 | 87.3 | 1.46584 | 46.7 | 89.6 | 1.48203 | 47.7 |
| 85.1 | 1.45055 | 45.6 | 87.4 | 1.46654 | 46.7 | 89.7 | 1.48274 | 47.8 |
| 85.2 | 1.45125 | 45.6 | 87.5 | 1.46724 | 46.7 | 89.8 | 1.48345 | 47.8 |
| 85.3 | 1.45193 | 45.7 | 87.6 | 1.46794 | 46.8 | 89.9 | 1.48416 | 47.9 |
| 85.4 | 1.45262 | 45.7 | 87.7 | 1.46864 | 46.8 | 90.0 | 1.48486 | 47.9 |

calulated.)

| 15.5 | 16.0 | 16.5 | 17.0 | 17.5 | 18.0 | 18.5 | 19.0 | 19.5 | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | Polariscope reading Degrees |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .2 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.26 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 1 |
| .5 | 0.54 | 0.54 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 2 |
| 8 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.79 | 0.79 | 0.79 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 3 |
| .0 | 1.07 | 1.07 | 1.07 | 1.07 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 4 |
| .3 | 1.34 | 1.34 | 1.34 | 1.33 | 1.33 | 1.33 | 1.32 | 1.32 | 1.32 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 5 |
| .6 | 1.61 | 1.61 | 1.60 | 1.60 | 1.60 | 1.59 | 1.59 | 1.59 | 1.58 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 6 |
| .8 | 1.88 | 1.87 | 1.87 | 1 86 | 1.86 | 1.86 | 1.85 | 1.85 | 1.85 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 7 |
| .1 | 2.15 | 2.14 | 2.14 | 2.13 | 2.13 | 2.12 | 2.12 | 2.12 | 2.11 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 8 |
| .4 | 2.41 | 2.41 | 2.40 | 2.40 | 2.39 | 2.39 | 2.38 | 2.38 | 2.37 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 9 |
| .69 | 2.68 | 2.68 | 2.67 | 2.67 | 2.66 | 2.65 | 2.65 | 2.64 | 2.64 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 10 |
| .95 | 2.95 | 2.94 | 2.94 | 2.93 | 2.92 | 2.92 | 2.91 | 2.91 | 2.90 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 11 |
| .22 | 3.22 | 3.21 | 3.20 | 3.20 | 3.19 | 3.18 | 3 18 | 3.17 | 3.17 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 12 |
| .49 | 3.49 | 3.48 | 3.47 | 3.46 | 3.46 | 3.45 | 3.44 | 3.44 | 3.43 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 13 |
| .76 | 3.75 | 3.75 | 3.74 | 3.73 | 3.72 | 3.72 | 3.71 | 3.70 | 3.69 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 14 |
| .03 | 4.02 | 4.02 | 4.01 | 4.00 | 3.99 | 3.98 | 3.97 | 3.97 | 3.96 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 15 |
| .30 | 4.29 | 4.28 | 4.27 | 4.26 | 4.26 | 4.25 | 4.24 | 4.23 | 4.22 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 16 |
| .57 | 4.56 | 4.55 | 4.54 | 4.53 | 4.52 | 4.51 | 4.50 | 4.49 | 4.48 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 17 |
| .84 | 4.83 | 4.82 | 4.81 | 4.80 | 4.79 | 4.78 | 4.77 | 4.76 | 4.75 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 18 |
| .11 | 5.10 | 5.09 | 5.08 | 5.06 | 5.05 | 5.04 | 5.03 | 5.02 | 5.01 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 19 |
| .38 | 5.36 | 5.35 | 5.34 | 5.33 | 5.32 | 5.31 | 5.30 | 5.29 | 5.28 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 20 |
| .65 | 5.63 | 5.62 | 5.61 | 5.60 | 5.59 | 5.58 | 5.56 | 5.55 | 5.54 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 21 |
| .91 | 5.90 | 5.89 | 5.88 | 5.87 | 5.85 | 5.84 | 5.83 | 5.82 | 5.80 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 22 |
| .18 | 6.17 | 6.16 | 6.14 | 6.13 | 6.12 | 6.11 | 6.09 | 6.08 | 6 07 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 23 |
| .45 | 6.44 | 6.43 | 6.41 | 6.40 | 6.39 | 6.37 | 6.36 | 6.35 | 6.33 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 24 |
| .72 | 6.71 | 6.69 | 6.68 | 6.67 | 6.65 | 6.64 | 6.63 | 6.61 | 6.60 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 25 |
| .99 | 6.97 | 6.96 | 6.95 | 6.93 | 6.92 | 6.90 | 6.89 | 6 88 | 6.86 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 26 |
| .26 | 7.24 | 7.23 | 7.21 | 7.20 | 7.18 | 7.17 | 7.15 | 7.14 | 7.13 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 27 |
| .53 | 7.51 | 7.50 | 7.48 | 7.47 | 7.45 | 7.44 | 7.42 | 7.40 | 7.39 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 28 |
| .80 | 7.78 | 7.77 | 7.75 | 7.73 | 7.72 | 7.70 | 7.68 | 7.67 | 7.65 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 29 |
| .06 | 8.05 | 8.03 | 8.02 | 8.00 | 7.98 | 7.97 | 7 95 | 7.93 | 7.92 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 30 |
| .33 | 8.32 | 8.30 | 8.28 | 8.27 | 8.25 | 8.23 | 8.21 | 8.20 | 8.18 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 31 |
| .60 | 8.58 | 8.57 | 8.55 | 8.53 | 8.51 | 8.50 | 8.48 | 8.46 | 8.45 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 32 |
| .87 | 8.85 | 8.84 | 8.82 | 8.80 | 8.78 | 8.76 | 8.75 | 8.73 | 8.71 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 33 |
| .14 | 9.12 | 9.10 | 9.09 | 9.07 | 9.05 | 9.03 | 9.01 | 8.99 | 8.97 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 34 |
| .41 | 9.39 | 9.37 | 9.35 | 9.34 | 9.32 | 9.30 | 9.28 | 9.26 | 9.24 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 35 |
| .68 | 9.66 | 9.64 | 9.62 | 9.60 | 9.58 | 9.56 | 9.54 | 9.52 | 9.50 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 36 |
| .95 | 9.93 | 9.91 | 9.89 | 9.87 | 9.85 | 9.83 | 9.81 | 9.79 | 9.77 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 37 |
| .22 | 10.20 | 10.18 | 10.15 | 10.13 | 10.11 | 10.09 | 10.07 | 10.05 | 10.03 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 38 |
| .49 | 10.46 | 10.44 | 10.42 | 10.40 | 10.38 | 10.36 | 10.34 | 10.32 | 10.29 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 39 |
| .76 | 10.73 | 10.71 | 10.69 | 10.67 | 10.64 | 10.62 | 10.60 | 10.58 | 10.56 | 10.54 | 10.52 | 10.49 | 10.47 | 10.45 | 10.43 | 10.41 | 10.38 | 40 |
| .03 | 11.00 | 10.98 | 10.96 | 10.94 | 10.91 | 10.89 | 10.87 | 10.85 | 10.82 | 10.80 | 10.78 | 10.76 | 10.74 | 10.71 | 10.69 | 10.67 | 10.65 | 41 |
| .29 | 11.27 | 11.25 | 11.23 | 11.20 | 11.18 | 11.16 | 11.13 | 11.11 | 11.09 | 11.07 | 11.04 | 11.02 | 11.00 | 10.97 | 10.95 | 10.93 | 10.90 | 42 |
| .56 | 11.54 | 11.52 | 11.49 | 11.47 | 11.45 | 11.42 | 11.40 | 11.38 | 11.35 | 11.33 | 11.31 | 11.28 | 11.26 | 11.24 | 11.21 | 11.19 | 11.17 | 43 |
| .83 | 11.81 | 11.79 | 11.76 | 11.74 | 11.71 | 11.69 | 11.66 | 11.64 | 11.62 | 11.59 | 11.57 | 11.55 | 11.52 | 11.50 | 11.47 | 11.45 | 11.42 | 44 |
| .10 | 12.08 | 12.05 | 12.03 | 12.01 | 11.98 | 11.96 | 11.93 | 11.91 | 11.88 | 11.84 | 11.83 | 11.81 | 11.78 | 11.76 | 11.73 | 11.71 | 11.69 | 45 |
| .37 | 12.35 | 12.32 | 12.30 | 12.27 | 12.25 | 12.22 | 12.20 | 12.17 | 12.15 | 12.13 | 12.09 | 12.07 | 12.05 | 12.02 | 12.00 | 11.97 | 11.94 | 46 |
| .64 | 12.61 | 12.59 | 12.56 | 12.54 | 12.51 | 12.49 | 12.46 | 12.44 | 12.41 | 12.39 | 12.36 | 12.33 | 12.31 | 12 28 | 12.26 | 12.23 | 12.21 | 47 |
| .91 | 12.88 | 12.86 | 12.83 | 12.81 | 12.78 | 12.75 | 12.73 | 12.70 | 12.67 | 12.65 | 12.62 | 12.60 | 12.57 | 12.54 | 12.52 | 12.49 | 12.47 | 48 |
| .18 | 13.15 | 13.13 | 13.10 | 13.07 | 13.05 | 13.02 | 12.99 | 12.97 | 12.94 | 12.91 | 12.88 | 12.86 | 12.83 | 12.81 | 12.78 | 12.75 | 12.73 | 49 |
| .45 | 13.42 | 13.40 | 13.37 | 13.34 | 13.31 | 13.29 | 13.26 | 13.23 | 13.20 | 13.17 | 13.15 | 13.12 | 13.09 | 13.07 | 13.04 | 13.01 | 12.99 | 50 |
| .72 | 13.69 | 13.66 | 13.64 | 13.61 | 13.58 | 13.55 | 13.52 | 13.50 | 13.47 | 13.44 | 13.41 | 13.39 | 13.36 | 13.33 | 13.30 | 13.27 | 13.25 | 51 |
| .99 | 13.96 | 13.93 | 13.90 | 13.88 | 13.85 | 13.82 | 13.79 | 13.76 | 13.73 | 13.70 | 13.68 | 13.65 | 13.62 | 13.59 | 13.56 | 13.53 | 13.51 | 52 |
| .26 | 14.23 | 14.20 | 14.17 | 14.14 | 14.11 | 14.08 | 14.05 | 14.03 | 14.00 | 13.97 | 13.94 | 13.91 | 13.88 | 13.85 | 13.82 | 13.79 | 13.77 | 53 |
| .53 | 14.50 | 14.47 | 14.44 | 14.41 | 14.38 | 14.35 | 14.32 | 14.29 | 14.26 | 14.23 | 14.20 | 14.17 | 14.14 | 14.11 | 14.08 | 14.06 | 14.02 | 54 |
| .80 | 14.77 | 14.74 | 14.71 | 14.68 | 14.65 | 14.62 | 14.59 | 14.56 | 14.53 | 14.50 | 14.47 | 14.44 | 14.41 | 14.38 | 14.35 | 14.32 | 14.29 | 55 |
| . . | 15.03 | 15.00 | 14.97 | 14.94 | 14 91 | 14.88 | 14.85 | 14.82 | 14.79 | 14.76 | 14.73 | 14.70 | 14.67 | 14.64 | 14.61 | 14.58 | 14.55 | 56 |
| . . | 15.30 | 15.27 | 15.24 | 15.21 | 15.18 | 15.15 | 15.12 | 15.09 | 15.06 | 15.02 | 14.99 | 14.96 | 14.93 | 14.90 | 14.87 | 14.84 | 14.81 | 57 |
| . . | 15.57 | 15.54 | 15.51 | 15.48 | 15.45 | 15.42 | 15.38 | 15.35 | 15.32 | 15.29 | 15.26 | 15.23 | 15.19 | 15.16 | 15.13 | 15.10 | 15.07 | 58 |
| . . | . . . | 15.81 | 15.78 | 15.75 | 15.71 | 15.68 | 15.65 | 15.62 | 15.58 | 15.55 | 15.52 | 15.49 | 15.46 | 15.42 | 15.39 | 15.36 | 15.33 | 59 |
| . . | . . . | . . | 16.05 | 16.01 | 15.98 | 15 95 | 15.92 | 15.88 | 15.85 | 15.82 | 15.78 | 15.75 | 15.72 | 15.69 | 15.65 | 15.62 | 15.59 | 60 |
| . . | . . . | . . . | 16.31 | 16.28 | 16.25 | 16.21 | 16.18 | 16.15 | 16.11 | 16.08 | 16.05 | 16.01 | 15.98 | 15.95 | 15.91 | 15.88 | 15.85 | 61 |
| . . | . . | . . . | . . . | 16.55 | 16.52 | 16.48 | 16.45 | 16.41 | 16.38 | 16.35 | 16.31 | 16.28 | 16.24 | 16.21 | 16.18 | 16.14 | 16.11 | 62 |
| . . | . . . | . . . | . . . | 16.82 | 16.78 | 16.75 | 16.71 | 16.68 | 16.64 | 16.61 | 16.57 | 16.54 | 16.51 | 16.47 | 16.44 | 16.40 | 16.37 | 63 |
| . . | . . . | . . . | . . . | . . . | 17.03 | 17.01 | 16.98 | 16.94 | 16.91 | 16.87 | 16.84 | 16.80 | 16.77 | 16.73 | 16.70 | 16.66 | 16 63 | 64 |
| . . | . . . | . . . | . . . | . . . | 17.32 | 17.28 | 17.24 | 17.21 | 17.17 | 17.14 | 17.10 | 17.07 | 17.03 | 17.00 | 16.96 | 16.92 | 16.89 | 65 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | 17.51 | 17.47 | 17.44 | 17.40 | 17.37 | 17.33 | 17.29 | 17.26 | 17.22 | 17.19 | 17.15 | 66 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | 17.78 | 17.74 | 17.70 | 17.67 | 17.63 | 17.59 | 17.56 | 17.52 | 17.48 | 17.45 | 17.41 | 67 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | 18.04 | 18.00 | 17.97 | 17.93 | 17.89 | 17.86 | 17.82 | 17.78 | 17.74 | 17.71 | 17.67 | 68 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | 18.31 | 18.27 | 18.23 | 18.19 | 18.16 | 18.12 | 18.08 | 18.04 | 18.00 | 17.97 | 17.93 | 69 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 18.53 | 18.50 | 18.46 | 18.42 | 18.38 | 18.35 | 18.31 | 18.27 | 18 23 | 18.19 | 70 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 18.76 | 18.72 | 18.68 | 18.65 | 18.61 | 18.57 | 18.53 | 18.49 | 18.45 | 71 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 19.03 | 18.99 | 18.95 | 18.91 | 18.87 | 18.83 | 18.79 | 18.75 | 18.71 | 72 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 19.25 | 19.21 | 19.17 | 19.13 | 19.09 | 19.05 | 19.01 | 18.97 | 73 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . | . . . | . . . | 19.52 | 19.48 | 19.44 | 19.40 | 19.35 | 19.31 | 19.27 | 19.23 | 74 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 19.74 | 19.70 | 19.66 | 19.62 | 19.57 | 19.53 | 19.49 | 75 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 20.00 | 19.96 | 19.92 | 19.88 | 19.84 | 19.80 | 19.75 | 76 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 20.27 | 20.22 | 20.18 | 20.14 | 20.10 | 20.06 | 20.01 | 77 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 20.49 | 20.45 | 20.40 | 20.36 | 20.32 | 20.27 | 78 |
| . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 20.75 | 20.71 | 20.66 | 20.62 | 20.58 | 20.54 | 79 |
| . . | . . . | . . . | . . . | . . . | . . . | . . | . . . | . . . | . . . | . . . | . . . | . . . | 20.97 | 20.93 | 20.88 | 20.54 | 20.80 | 80 |

## TABLE IV.

### COMMERCIAL ATOMIC WEIGHTS FOR ANALYTICAL PURPOSES.

| Substance | Symbol | Weight |
|---|---|---|
| Aluminum | Al | 27.1 |
| Antimony | Sb | 120.0 |
| Arsenic | As | 75.0 |
| Barium | Ba | 137.0 |
| Bismuth | Bi | 208.0 |
| Bromine | Br | 80.0 |
| Cadmium | Cd | 112.0 |
| Calcium | Ca | 40.0 |
| Carbon | C | 12.0 |
| Chlorine | Cl | 35.5 |
| Chromium | Cr | 52.0 |
| Cobalt | Co | 59.0 |
| Copper | Cu | 63.5 |
| Hydrogen | H | 1.0 |
| Iodine | I | 127.0 |
| Iron | Fe | 56.0 |
| Lead | Pb | 207.0 |
| Magnesium | Mg | 24.0 |
| Manganese | Mn | 55.0 |
| Mercury | Hg | 200.0 |
| Molybdenum | Mo | 96.0 |
| Nickel | Ni | 58.8 |
| Nitrogen | N | 14.0 |
| Oxygen | O | 16.0 |
| Phosphorus | P | 31.0 |
| Platinum | Pt | 195.0 |
| Potassium | K | 39.0 |
| Silicon | Si | 28.4 |
| Silver | Ag | 108.0 |
| Sodium | Na | 23.0 |
| Strontium | Sr | 87.5 |
| Sulphur | S | 32.0 |
| Tin | Sn | 119.0 |
| Titanum | Ti | 48.0 |
| Tungsten | W | 184.0 |
| Zinc | Zn | 65.0 |

## TABLE V.

### TABLE OF FACTORS.

| Element | Substance found | Substance sought | Factor |
|---|---|---|---|
| Aluminum | $Al_2O_3$ | Al | 0.53033 |
| | $AlPO_4$ | Al | 0.22195 |
| | $AlPO_4$ | $Al_2O_3$ | 0.41851 |
| Ammonium | $(NH_4)_2PtCl_6$ | $NH_4$ | 0.08108 |
| | $(NH_4)_2PtCl_6$ | $NH_4Cl$ | 0.24099 |
| | $(NH_4)_2PtCl_6$ | $NH_3$ | 0.07658 |
| | Pt | $NH_4$ | 0.18461 |
| | Pt | $NH_3$ | 0.17436 |
| Barium | $BaSO_4$ | Ba | 0.58798 |
| | $BaSO_4$ | BaO | 0.65666 |
| | $BaCO_3$ | Ba | 0.69543 |
| | $BaCO_3$ | BaO | 0.77662 |
| | $BaCrO_4$ | Ba | 0.54154 |
| | $BaCrO_4$ | BaO | 0.60474 |
| Calium | CaO | Ca | 0.71429 |
| | CaO | CaCO | 1.77500 |
| | $CaCO_3$ | Ca | 0.40000 |
| | $CaCO_3$ | CaO | 0.56000 |
| | $CaSO_4$ | Ca | 0.29411 |
| | $CaSO_4$ | CaO | 0.41176 |
| Carbon | CO | C | 0.27273 |
| | $BaCO_3$ | C | 0.06091 |
| | $BaCO_3$ | $CO_2$ | 0.22335 |
| | $CaCO_3$ | $CO_2$ | 0.44000 |
| Chlorine | AgCl | Cl | 0.24725 |
| Hydrogen | $H_2O$ | H | 0.11111 |
| Iron | $Fe_2O_3$ | Fe | 0.70000 |
| | $Fe_2O_3$ | FeO | 0.90000 |
| | $Fe_2O_3$ | $FeS_2$ | 1.50000 |
| | Fe | FeO | 1.28571 |
| | Fe | $Fe_2O_3$ | 1.42859 |
| | Fe | $FeS_2$ | 2.14286 |
| | $FePO_4$ | FeO | 0.47682 |
| | $FePO_4$ | $Fe_2O_3$ | 0.52980 |
| | $FePO_4$ | Fe | 0.37086 |
| Magnesium | MgO | Mg | 0.60000 |
| | MgO | $MgCO_3$ | 2.10000 |
| | $Mg_2P_2O_7$ | Mg | 0.21621 |
| | $Mg_2P_2O_7$ | MgO | 0.36036 |
| Nitrogen | $(NH_4)_2PtCl_6$ | N | 0.06306 |
| | Pt | N | 0.14359 |

TABLE V—(*Continued*)

| Element | Substance found | Substance sought | Factor |
|---|---|---|---|
| Phosphorus | $Mg_2P_2O_7$ | P | 0.27028 |
| | $Mg_2P_2O_7$ | $P_2O_5$ | 0.63964 |
| | $Mg_2P_2O_7$ | $PO_4$ | 0.85586 |
| | $Mg_2P_2O_7$ | $Ca_3(PO_4)_2$ | 1.39640 |
| | $P_2O_5$ | P | 0.43661 |
| | P | $P_2O_5$ | 2.29032 |
| | $P_2O_5$ | $Ca_3(PO_4)_2$ | 2.18310 |
| Potassium | KCl | K | 0.52349 |
| | KCl | $K_2O$ | 0.63087 |
| | KCl | $K_2CO_3$ | 0.92618 |
| | $K_2SO_4$ | K | 0.44828 |
| | $K_2SO_4$ | $K_2O$ | 0.54023 |
| | $K_2PtCl_6$ | K | 0.16049 |
| | $K_2PtCl_6$ | $K_2O$ | 0.19342 |
| | $K_2PtCl_6$ | KCl | 0.30658 |
| | $KClO_4$ | K | 0.28159 |
| | $KClO_4$ | $K_2O$ | 0.33935 |
| | $KClO_4$ | KCl | 0.53791 |
| Silicon | $SiO_2$ | Si | 0.47020 |
| | Si | $SiO_2$ | 2.12676 |
| Sodium | NaCl | Na | 0.39316 |
| | NaCl | $Na_2O$ | 0.52991 |
| | $Na_2SO_4$ | Na | 0.32394 |
| | $Na_2SO_4$ | $Na_2O$ | 0.43662 |
| | $Na_2SO_4$ | $Na_2CO_3$ | 0.74648 |
| Sulphur | $BaSO_4$ | S | 0.13734 |
| | $BaSO_4$ | $SO_2$ | 0.27467 |
| | $BaSO_4$ | $SO_3$ | 0.34339 |
| | $BaSO_4$ | $SO_4$ | 0.41201 |
| | $BaSO_4$ | $H_2SO_4$ | 0.42060 |
| | $BaSO_4$ | $H_2S$ | 0.14592 |
| Zinc | ZnO | Zn | 0.80247 |
| | ZnS | Zn | 0.67010 |
| | $Zn_2P_2O_7$ | Zn | 0.42763 |

## TABLE VI.

### TABLE FOR THE DETERMINATION OF THE COEFFICIENT OF PURITY. (ROTTMAN.)

| Per cent. sugar | Per cent. NS = Brix minus sugar | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 |
| 8.0 | 88.9 | 87.9 | 87.0 | 86.0 | 85.1 | 84.2 | 83.3 | 82.5 | 81.6 |
| 8.2 | 89.1 | 88.2 | 87.2 | 86.3 | 85.4 | 84.5 | 83.7 | 82.8 | 82.0 |
| 8.4 | 89.4 | 88.4 | 87.5 | 86.6 | 85.7 | 84.8 | 84.0 | 83.2 | 82.3 |
| 8.6 | 89.6 | 88.7 | 87.8 | 86.9 | 86.0 | 85.1 | 84.3 | 83.5 | 82.7 |
| 8.8 | 89.8 | 88.9 | 88.0 | 87.1 | 86.3 | 85.4 | 84.6 | 83.8 | 83.0 |
| 9.0 | 90.0 | 89.1 | 88.2 | 87.4 | 86.5 | 85.7 | 84.9 | 84.1 | 83.3 |
| 9.2 | 90.2 | 89.3 | 88.5 | 87.6 | 86.8 | 86.0 | 85.2 | 84.4 | 83.6 |
| 9.4 | 90.4 | 89.5 | 88.7 | 87.8 | 87.0 | 86.2 | 85.5 | 84.7 | 83.9 |
| 9.6 | 90.6 | 89.7 | 88.9 | 88.1 | 87.3 | 86.5 | 85.7 | 85.0 | 84.2 |
| 9.8 | 90.7 | 89.9 | 89.1 | 88.3 | 87.5 | 86.7 | 86.0 | 85.2 | 84.5 |
| 10.0 | 90.9 | 90.1 | 89.3 | 88.5 | 87.7 | 87.0 | 86.2 | 85.5 | 84.7 |
| 10.2 | 91.1 | 90.3 | 89.5 | 88.7 | 87.9 | 87.2 | 86.4 | 85.7 | 85.0 |
| 10.4 | 91.2 | 90.4 | 89.7 | 88.9 | 88.1 | 87.4 | 86.7 | 86.0 | 85.2 |
| 10.6 | 91.4 | 90.6 | 89.8 | 89.1 | 88.3 | 87.6 | 86.9 | 86.2 | 85.5 |
| 10.8 | 91.5 | 90.8 | 90.0 | 89.3 | 88.5 | 87.8 | 87.1 | 86.4 | 85.7 |
| 11.0 | 91.7 | 90.9 | 90.2 | 89.4 | 88.7 | 88.0 | 87.3 | 86.6 | 85.9 |
| 11.2 | 91.8 | 91.1 | 90.3 | 89.6 | 88.9 | 88.2 | 87.5 | 86.8 | 86.2 |
| 11.4 | 91.9 | 91.2 | 90.5 | 89.8 | 89.1 | 88.4 | 87.7 | 87.0 | 86.4 |
| 11.6 | 92.1 | 91.3 | 90.6 | 89.9 | 89.2 | 88.5 | 87.9 | 87.2 | 86.6 |
| 11.8 | 92.2 | 91.5 | 90.8 | 90.1 | 89.4 | 88.7 | 88.1 | 87.4 | 86.8 |
| 12.0 | 92.3 | 91.6 | 90.9 | 90.2 | 89.6 | 88.9 | 88.2 | 87.6 | 87.0 |
| 12.2 | 92.4 | 91.7 | 91.0 | 90.4 | 89.7 | 89.1 | 88.4 | 87.8 | 87.1 |
| 12.4 | 92.5 | 91.9 | 91.2 | 90.5 | 89.9 | 89.2 | 88.6 | 87.9 | 87.3 |
| 12.6 | 92.6 | 92.0 | 91.3 | 90.6 | 90.0 | 89.4 | 88.7 | 88.1 | 87.5 |
| 12.8 | 92.7 | 92.1 | 91.4 | 90.8 | 90.1 | 89.5 | 88.9 | 88.3 | 87.7 |
| 13.0 | 92.8 | 92.2 | 91.5 | 90.9 | 90.3 | 89.7 | 89.0 | 88.4 | 87.8 |
| 13.2 | 92.9 | 92.3 | 91.7 | 91.0 | 90.4 | 89.8 | 89.2 | 88.6 | 88.0 |
| 13.4 | 93.0 | 92.4 | 91.8 | 91.2 | 90.5 | 89.9 | 89.3 | 88.7 | 88.2 |
| 13.6 | 93.1 | 92.5 | 91.9 | 91.3 | 90.7 | 90.1 | 89.5 | 88.9 | 88.3 |
| 13.8 | 93.2 | 92.6 | 92.0 | 91.4 | 90.8 | 90.2 | 89.6 | 89.0 | 88.5 |
| 14.0 | 93.2 | 92.7 | 92.1 | 91.5 | 90.9 | 90.3 | 89.7 | 89.2 | 88.6 |
| 14.2 | 93.3 | 92.8 | 92.2 | 91.6 | 91.0 | 90.4 | 89.9 | 89.3 | 88.8 |
| 14.4 | 93.4 | 92.9 | 92.3 | 91.7 | 91.1 | 90.6 | 90.0 | 89.4 | 88.9 |
| 14.6 | 93.5 | 93.0 | 92.4 | 91.8 | 91.3 | 90.7 | 90.1 | 89.6 | 89.0 |
| 14.8 | 93.6 | 63.1 | 92.5 | 91.9 | 91.4 | 90.8 | 90.2 | 89.7 | 89.2 |
| 15.0 | 93.7 | 93.2 | 92.6 | 92.0 | 91.5 | 90.9 | 90.4 | 89.8 | 89.3 |
| 15.2 | 93.8 | 93.3 | 92.7 | 92.1 | 91.6 | 91.0 | 90.5 | 89.9 | 89.4 |
| 15.4 | 93.9 | 93.3 | 92.8 | 92.2 | 91.7 | 91.1 | 90.6 | 90.1 | 89.5 |
| 15.6 | 94.0 | 93.4 | 92.8 | 92.3 | 91.8 | 91.2 | 90.7 | 90.2 | 89.7 |
| 15.8 | 94.1 | 93.5 | 92.9 | 92.4 | 91.9 | 91.3 | 90.8 | 90.3 | 89.8 |
| 16.0 | 94.1 | 93.6 | 93.0 | 92.5 | 92.0 | 91.4 | 90.9 | 90.4 | 89.9 |
| 16.2 | 94.2 | 93.7 | 93.1 | 92.6 | 92.0 | 91.5 | 91.0 | 90.5 | 90.0 |
| 16.4 | 94.3 | 93.7 | 93.2 | 92.6 | 92.1 | 91.6 | 91.1 | 90.6 | 90.1 |
| 16.6 | 94.3 | 93.8 | 93.3 | 92.7 | 92.2 | 91.7 | 91.2 | 90.7 | 90.2 |
| 16.8 | 94.4 | 73.9 | 93.3 | 92.8 | 92.3 | 91.8 | 91.3 | 90.8 | 90.3 |
| 17.0 | 94.4 | 93.9 | 93.4 | 92.9 | 92.4 | 91.9 | 91.4 | 90.9 | 90.4 |

TABLE VI—(*Continued*).

| Per cent. sugar | Per cent. NS = Brix minus sugar | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 |
| 8.0 | 80.8 | 80.0 | 79.2 | 78.4 | 77.7 | 76.9 | 76.2 | 75.5 | 74.8 |
| 8.2 | 81.2 | 80.4 | 79.6 | 78.8 | 78.1 | 77.4 | 76.6 | 75.9 | 75.2 |
| 8.4 | 81.5 | 80.8 | 80.0 | 79.2 | 78.5 | 77.8 | 77.1 | 76.4 | 75.7 |
| 8.6 | 81.9 | 81.1 | 80.4 | 79.6 | 78.9 | 78.2 | 77.5 | 76.8 | 76.1 |
| 8.8 | 82.2 | 81.5 | 80.7 | 80.0 | 79.3 | 78.6 | 77.9 | 77.2 | 76.5 |
| 9.0 | 82.6 | 81.8 | 81.1 | 80.4 | 79.6 | 78.9 | 78.3 | 77.6 | 76.9 |
| 9.2 | 82.9 | 82.1 | 81.4 | 80.7 | 80.0 | 79.3 | 78.6 | 77.9 | 77.3 |
| 9.4 | 83.2 | 82.5 | 81.7 | 81.0 | 80.3 | 79.9 | 79.0 | 78.3 | 77.7 |
| 9.6 | 83.5 | 82.8 | 82.1 | 81.4 | 80.7 | 80.0 | 79.3 | 78.7 | 78.0 |
| 9.8 | 83.8 | 83.1 | 82.4 | 81.7 | 81.0 | 80.3 | 79.7 | 79.0 | 78.4 |
| 10.0 | 84.0 | 83.3 | 82.6 | 82.0 | 81.3 | 80.6 | 80.0 | 79.4 | 78.7 |
| 10.2 | 84.3 | 83.6 | 82.9 | 82.3 | 81.6 | 81.0 | 80.3 | 79.7 | 79.1 |
| 10.4 | 84.6 | 83.9 | 83.2 | 82.5 | 81.9 | 81.2 | 80.6 | 80.0 | 79.4 |
| 10.6 | 84.8 | 84.1 | 83.5 | 82.8 | 82.2 | 81.5 | 80.9 | 80.3 | 79.7 |
| 10.8 | 85.0 | 84.4 | 83.7 | 83.1 | 82.4 | 81.8 | 81.2 | 80.6 | 80.0 |
| 11.0 | 85.3 | 84.6 | 84.0 | 83.3 | 82.7 | 82.1 | 81.5 | 80.9 | 80.3 |
| 11.2 | 85.5 | 84.8 | 84.2 | 83.6 | 83.0 | 82.4 | 81.8 | 81.2 | 80.6 |
| 11.4 | 85.7 | 85.1 | 84.4 | 83.8 | 83.2 | 82.6 | 82.0 | 81.4 | 80.9 |
| 11.6 | 85.9 | 85.3 | 84.7 | 84.1 | 83.5 | 82.9 | 82.3 | 81.7 | 81.1 |
| 11.8 | 86.1 | 85.5 | 84.9 | 84.3 | 83.7 | 83.1 | 82.5 | 81.9 | 81.4 |
| 12.0 | 86.3 | 85.7 | 85.1 | 84.5 | 83.9 | 83.3 | 82.8 | 82.2 | 81.6 |
| 12.2 | 86.5 | 85.9 | 85.3 | 84.7 | 84.1 | 83.6 | 83.0 | 82.4 | 81.9 |
| 12.4 | 86.7 | 86.1 | 85.5 | 84.9 | 84.4 | 83.8 | 83.2 | 82.7 | 82.1 |
| 12.6 | 86.9 | 86.3 | 85.7 | 85.1 | 84.6 | 84.0 | 83.4 | 82.9 | 82.4 |
| 12.8 | 87.1 | 86.5 | 85.9 | 85.3 | 84.8 | 84.2 | 83.7 | 83.1 | 82.6 |
| 13.0 | 87.2 | 86.7 | 86.1 | 85.5 | 85.0 | 84.4 | 83.9 | 83.3 | 82.8 |
| 13.2 | 87.4 | 86.8 | 86.3 | 85.7 | 85.2 | 84.6 | 84.1 | 83.5 | 83.0 |
| 13.4 | 87.6 | 87.0 | 86.5 | 85.9 | 85.4 | 84.8 | 84.3 | 83.7 | 83.2 |
| 13.6 | 87.7 | 87.2 | 86.6 | 86.1 | 85.5 | 85.0 | 84.5 | 83.9 | 83.4 |
| 13.8 | 87.9 | 87.3 | 86.8 | 86.3 | 85.7 | 85.2 | 84.7 | 84.1 | 83.6 |
| 14.0 | 88.1 | 87.5 | 87.0 | 86.4 | 85.9 | 85.4 | 84.8 | 84.3 | 83.8 |
| 14.2 | 88.2 | 87.7 | 87.1 | 86.6 | 86.1 | 85.5 | 85.0 | 84.5 | 84.0 |
| 14.4 | 88.3 | 87.8 | 87.3 | 86.7 | 86.2 | 85.7 | 85.2 | 84.7 | 84.2 |
| 14.6 | 88.5 | 88.0 | 87.4 | 86.9 | 86.4 | 85.9 | 85.4 | 84.9 | 84.4 |
| 14.8 | 88.6 | 88.1 | 87.6 | 87.1 | 86.5 | 86.0 | 85.5 | 85.1 | 84.6 |
| 15.0 | 88.8 | 88.2 | 87.7 | 87.2 | 86.7 | 86.2 | 85.7 | 85.2 | 84.7 |
| 15.2 | 88.9 | 88.4 | 87.9 | 87.4 | 86.9 | 86.4 | 85.9 | 85.4 | 84.9 |
| 15.4 | 89.0 | 88.5 | 88.0 | 87.5 | 87.0 | 86.5 | 86.0 | 85.6 | 85.1 |
| 15.6 | 89.1 | 88.6 | 88.1 | 87.6 | 87.2 | 86.7 | 86.2 | 85.7 | 85.2 |
| 15.8 | 89.3 | 88.8 | 88.3 | 87.8 | 87.3 | 86.8 | 86.3 | 85.9 | 85.4 |
| 16.0 | 89.4 | 88.9 | 88.4 | 87.9 | 87.4 | 87.0 | 86.5 | 86.0 | 85.6 |
| 16.2 | 89.5 | 89.0 | 88.5 | 88.0 | 87.6 | 87.1 | 86.6 | 86.2 | 85.7 |
| 16.4 | 89.6 | 89.1 | 88.6 | 88.2 | 87.7 | 87.2 | 86.8 | 86.3 | 85.9 |
| 16.6 | 89.7 | 89.2 | 88.8 | 88.3 | 87.8 | 87.4 | 86.9 | 86.5 | 86.0 |
| 16.8 | 89.8 | 89.4 | 88.9 | 88.4 | 88.0 | 87.5 | 87.0 | 86.6 | 86.2 |
| 17.0 | 89.9 | 89.5 | 89.0 | 88.5 | 88.1 | 87.6 | 87.2 | 86.7 | 86.3 |

TABLE VI—(*Continued*).

| Per cent. sugar | Per cent. NS = Brix minus sugar | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
| 8.0 | 74.1 | 73.4 | 72.7 | 72.1 | 71.4 | 70.8 | 70.2 | 69.6 | 69.0 |
| 8.2 | 74.5 | 73.9 | 73.2 | 72.6 | 71.9 | 71.3 | 70.7 | 70.1 | 69.5 |
| 8.4 | 75.0 | 74.3 | 73.7 | 73.0 | 72.4 | 71.8 | 71.2 | 70.6 | 70.0 |
| 8.6 | 75.4 | 74.8 | 74.1 | 73.5 | 72.9 | 72.3 | 71.7 | 71.1 | 70.5 |
| 8.8 | 75.9 | 75.2 | 74.6 | 73.9 | 73.3 | 72.7 | 72.1 | 71.5 | 71.0 |
| 9.0 | 76.3 | 75.6 | 75.0 | 74.4 | 73.8 | 73.2 | 72.6 | 72.0 | 71.4 |
| 9.2 | 76.7 | 75.8 | 75.4 | 74.8 | 74.2 | 73.6 | 73.0 | 72.4 | 71.9 |
| 9.4 | 77.0 | 76.4 | 75.8 | 75.2 | 74.6 | 74.0 | 73.2 | 72.9 | 72.3 |
| 9.6 | 77.4 | 76.8 | 76.2 | 75.6 | 75.0 | 74.4 | 73.8 | 73.3 | 72.7 |
| 9.8 | 77.8 | 77.2 | 76.6 | 76.0 | 75.4 | 74.8 | 74.2 | 73.7 | 73.1 |
| 10.0 | 78.1 | 77.5 | 76.9 | 76.3 | 75.8 | 75.2 | 74.6 | 74.1 | 73.5 |
| 10.2 | 78.5 | 77.9 | 77.3 | 76.7 | 76.1 | 75.6 | 75.0 | 74.5 | 73.9 |
| 10.4 | 78.8 | 78.2 | 77.6 | 77.0 | 76.5 | 75.9 | 75.4 | 74.8 | 74.3 |
| 10.6 | 79.1 | 78.5 | 77.9 | 77.4 | 76.8 | 76.3 | 75.7 | 75.2 | 74.6 |
| 10.8 | 79.4 | 78.8 | 78.3 | 77.5 | 77.1 | 76.6 | 76.1 | 75.5 | 75.0 |
| 11.0 | 79.7 | 79.1 | 78.6 | 78.0 | 77.5 | 76.9 | 76.4 | 75.9 | 75.3 |
| 11.2 | 80.0 | 69.4 | 78.9 | 78.3 | 77.8 | 77.2 | 76.7 | 76.2 | 75.7 |
| 11.4 | 80.3 | 79.7 | 79.2 | 78.6 | 78.1 | 77.6 | 77.0 | 76.5 | 76.0 |
| 11.6 | 80.6 | 80.0 | 79.4 | 78.9 | 78.4 | 77.9 | 77.3 | 76.8 | 76.3 |
| 11.8 | 80.8 | 80.3 | 79.7 | 79.2 | 78.7 | 78.1 | 77.6 | 77.1 | 76.6 |
| 12.0 | 81.1 | 80.5 | 80.0 | 79.5 | 78.9 | 78.4 | 77.9 | 77.4 | 76.9 |
| 12.2 | 81.3 | 80.8 | 80.3 | 79.7 | 79.2 | 78.7 | 78.2 | 77.7 | 77.2 |
| 12.4 | 81.6 | 81.0 | 80.5 | 80.0 | 79.5 | 79.0 | 78.5 | 78.0 | 77.5 |
| 12.6 | 81.8 | 81.3 | 80.8 | 80.3 | 79.7 | 79.2 | 78.8 | 78.3 | 77.8 |
| 12.8 | 82.1 | 81.5 | 81.0 | 80.5 | 80.0 | 79.5 | 79.0 | 78.5 | 78.0 |
| 13.0 | 82.3 | 81.8 | 81.2 | 80.7 | 80.2 | 79.8 | 79.3 | 78.8 | 78.3 |
| 13.2 | 82.5 | 82.0 | 81.5 | 81.0 | 80.5 | 80.0 | 79.5 | 79.0 | 78.6 |
| 13.4 | 82.7 | 82.2 | 81.7 | 81.2 | 80.7 | 80.2 | 79.8 | 79.3 | 78.8 |
| 13.6 | 82.9 | 82.4 | 81.9 | 81.4 | 81.0 | 80.5 | 80.0 | 79.5 | 79.1 |
| 13.8 | 83.1 | 82.6 | 82.1 | 81.7 | 81.2 | 80.7 | 80.2 | 79.8 | 79.3 |
| 14.0 | 83.3 | 82.8 | 82.3 | 81.9 | 81.4 | 80.9 | 80.5 | 80.0 | 79.5 |
| 14.2 | 83.5 | 83.0 | 82.5 | 82.1 | 81.5 | 81.1 | 80.7 | 80.2 | 79.8 |
| 14.4 | 83.7 | 83.2 | 82.7 | 82.3 | 81.8 | 81.4 | 80.9 | 80.4 | 80.0 |
| 14.6 | 83.9 | 83.4 | 82.9 | 82.5 | 82.0 | 81.6 | 81.1 | 80.7 | 80.2 |
| 14.8 | 84.1 | 83.6 | 83.1 | 82.7 | 82.2 | 81.8 | 81.3 | 80.9 | 80.4 |
| 15.0 | 84.3 | 83.8 | 83.3 | 82.9 | 82.4 | 82.0 | 81.5 | 81.1 | 80.6 |
| 15.2 | 84.4 | 84.0 | 83.5 | 83.1 | 82.6 | 82.2 | 81.7 | 81.3 | 80.8 |
| 15.4 | 84.6 | 84.2 | 83.7 | 83.2 | 82.8 | 82.4 | 81.9 | 81.5 | 81.0 |
| 15.6 | 84.8 | 84.3 | 83.9 | 83.4 | 83.0 | 82.5 | 82.1 | 81.7 | 81.2 |
| 15.8 | 84.9 | 84.5 | 84.0 | 83.6 | 83.2 | 82.7 | 82.3 | 81.9 | 81.4 |
| 16.0 | 85.1 | 84.7 | 84.2 | 83.8 | 83.3 | 82.9 | 82.5 | 82.0 | 81.6 |
| 16.2 | 85.3 | 84.8 | 84.4 | 83.9 | 83.5 | 83.1 | 82.7 | 82.2 | 81.8 |
| 16.4 | 85.4 | 84.9 | 84.5 | 84.1 | 83.7 | 83.2 | 82.8 | 82.4 | 82.0 |
| 16.6 | 85.6 | 85.1 | 84.7 | 84.3 | 83.8 | 83.4 | 83.0 | 82.6 | 82.2 |
| 16.8 | 85.9 | 85.2 | 84.8 | 84.4 | 84.0 | 83.6 | 83.2 | 82.8 | 82.4 |
| 17.0 | 85.9 | 85.4 | 85.0 | 84.6 | 84.2 | 83.7 | 83.3 | 82.9 | 82.5 |

## TABLE VI—(*Continued*).

| Per cent. sugar | Per cent. NS = Brix minus sugar | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 | 4.5 |
| 8.0 | 68.4 | 67.8 | 67.2 | 66.7 | 66.1 | 65.6 | 65.0 | 64.5 | 64.0 |
| 8.2 | 68.9 | 68.3 | 67.8 | 67.2 | 66.7 | 66.1 | 65.6 | 65.1 | 64.6 |
| 8.4 | 69.4 | 68.8 | 68.3 | 67.7 | 67.2 | 66.7 | 66.1 | 65.6 | 65.1 |
| 8.6 | 69.9 | 69.3 | 68.8 | 68.3 | 67.7 | 67.2 | 66.7 | 66.2 | 65.6 |
| 8.8 | 70.4 | 69.8 | 69.3 | 68.8 | 68.2 | 67.7 | 67.2 | 66.7 | 66.2 |
| 9.0 | 79.9 | 70.3 | 69.8 | 69.2 | 68.7 | 68.2 | 67.7 | 67.2 | 66.7 |
| 9.2 | 71.3 | 70.8 | 70.2 | 69.7 | 69.2 | 68.7 | 68.1 | 67.6 | 67.2 |
| 9.4 | 71.8 | 71.2 | 70.7 | 70.1 | 69.6 | 69.1 | 68.6 | 68.1 | 67.6 |
| 9.6 | 72.2 | 71.6 | 71.1 | 70.6 | 70.1 | 69.6 | 69.1 | 68.6 | 68.1 |
| 9.8 | 72.6 | 72.1 | 71.5 | 71.0 | 70.5 | 70.0 | 69.5 | 69.0 | 68.5 |
| 10.0 | 73.0 | 72.5 | 71.9 | 71.4 | 70.9 | 70.4 | 69.9 | 69.4 | 69.0 |
| 10.2 | 73.4 | 72.9 | 72.3 | 71.8 | 71.3 | 70.8 | 70.3 | 69.9 | 69.4 |
| 10.4 | 73.8 | 73.2 | 72.7 | 72.2 | 71.7 | 71.2 | 70.7 | 70.3 | 69.8 |
| 10.6 | 74.1 | 73.6 | 73.1 | 72.6 | 72.1 | 71.6 | 71.1 | 70.7 | 70.2 |
| 10.8 | 74.5 | 74.0 | 73.5 | 73.0 | 72.5 | 72.0 | 71.5 | 71.1 | 70.6 |
| 11.0 | 74.8 | 74.3 | 73.8 | 73.3 | 72.8 | 72.4 | 71.9 | 71.4 | 71.0 |
| 11.2 | 75.2 | 74.7 | 74.2 | 73.7 | 73.2 | 72.7 | 72.3 | 71.8 | 71.3 |
| 11.4 | 75.5 | 75.0 | 74.5 | 74.0 | 73.5 | 73.1 | 72.6 | 72.2 | 71.7 |
| 11.6 | 75.8 | 75.3 | 74.8 | 74.4 | 73.9 | 73.4 | 73.0 | 72.5 | 72.0 |
| 11.8 | 76.1 | 75.6 | 75.2 | 74.9 | 74.2 | 73.8 | 73.3 | 72.8 | 72.4 |
| 12.0 | 76.4 | 75.9 | 75.5 | 75.0 | 74.5 | 74.1 | 73.6 | 73.2 | 72.7 |
| 12.2 | 76.7 | 76.2 | 75.8 | 75.3 | 74.8 | 74.4 | 73.9 | 73.5 | 73.1 |
| 12.4 | 77.4 | 76.5 | 76.1 | 75.6 | 75.2 | 74.7 | 74.3 | 73.8 | 73.4 |
| 12.6 | 77.3 | 76.8 | 76.4 | 75.9 | 75.4 | 75.0 | 74.6 | 74.1 | 73.7 |
| 12.8 | 77.6 | 77.1 | 76 6 | 76.2 | 75.7 | 75.3 | 74.9 | 74.4 | 74.0 |
| 13.0 | 77.8 | 77.4 | 76.9 | 76.5 | 76.0 | 75.6 | 75.1 | 74.7 | 74.3 |
| 13.2 | 78.1 | 77.6 | 77.2 | 76.7 | 76.3 | 75.9 | 75.4 | 75.0 | 74.6 |
| 13.4 | 78.4 | 77.9 | 77.5 | 77.0 | 76.6 | 76.1 | 75.7 | 75.3 | 74.9 |
| 13.6 | 78.6 | 78.2 | 77.7 | 77.3 | 76.8 | 76.4 | 76.0 | 75.6 | 75.1 |
| 13.8 | 78.9 | 78.4 | 78.0 | 77.5 | 77.1 | 76.7 | 76.2 | 75.8 | 75.4 |
| 14.0 | 79.1 | 78.7 | 78.2 | 77.8 | 77.3 | 76.9 | 76.5 | 76.1 | 75.7 |
| 14.2 | 79.3 | 78.9 | 78.5 | 78.0 | 77.6 | 77.2 | 76.8 | 76.3 | 75.9 |
| 14.4 | 79.6 | 79.1 | 78.7 | 78.3 | 77.8 | 77.4 | 77.0 | 76.6 | 76.2 |
| 14.6 | 79.8 | 79.3 | 78.9 | 78.5 | 78.1 | 77.6 | 77.2 | 76.8 | 76.4 |
| 14.8 | 80.0 | 79.6 | 79.1 | 78.7 | 78.3 | 77.9 | 77.5 | 77.1 | 76.7 |
| 15.0 | 80.2 | 79.8 | 79.4 | 78.9 | 78.5 | 78.1 | 77.7 | 77.3 | 76.9 |
| 15.2 | 80.4 | 80.0 | 79.6 | 79.2 | 78.8 | 78.4 | 77.9 | 77.6 | 77.2 |
| 15.4 | 80.6 | 80.2 | 79.8 | 79.4 | 79.0 | 78.6 | 78.2 | 77.8 | 77.4 |
| 15.6 | 80.8 | 80.4 | 80.0 | 79.6 | 79.2 | 78.8 | 78.4 | 78.0 | 77.6 |
| 15.8 | 81.0 | 80.6 | 80.2 | 79.8 | 79.4 | 79.0 | 78.6 | 78.2 | 77.8 |
| 16.0 | 81.2 | 80.8 | 80.4 | 80.0 | 79.6 | 79.2 | 78.8 | 78.4 | 78.0 |
| 16.2 | 81.4 | 81.0 | 80.6 | 80.2 | 79.8 | 79.4 | 79.0 | 78.6 | 78.3 |
| 16.4 | 81.6 | 81.2 | 80.8 | 80.4 | 80.0 | 79.6 | 79.2 | 78.8 | 78.5 |
| 16.6 | 81.8 | 81.4 | 81.0 | 80.6 | 80.2 | 79.8 | 79.4 | 79.0 | 78.7 |
| 16.8 | 82.0 | 81.6 | 81.2 | 80.8 | 80.4 | 80.0 | 79.6 | 79.2 | 78.9 |
| 17.0 | 82.1 | 81.7 | 81.3 | 81.0 | 80.6 | 80.2 | 79.8 | 79.4 | 79.1 |

## TABLE VII.

### COMPARISON OF THE THERMOMETRIC SCALES OF CELSIUS AND FAHRENHEIT.

| Celsius | Fahrenheit | Celsius | Fahrenheit | Celsius | Fahrenheit | Celsius | Fahrenheit |
|---|---|---|---|---|---|---|---|
| +100 | +212.0 | 65 | 149.0 | 30 | 86.0 | 5 | 23.0 |
| 99 | 210.2 | 64 | 147.2 | 29 | 84.2 | 6 | 21.2 |
| 98 | 208.4 | 63 | 145.4 | 28 | 82.4 | 7 | 19.4 |
| 97 | 206.4 | 62 | 143.6 | 27 | 80.6 | 8 | 17.6 |
| 96 | 204.8 | 61 | 141.8 | 26 | 78.8 | 9 | 15.8 |
| 95 | 203.0 | 60 | 140.0 | 25 | 77.0 | 10 | 14.0 |
| 94 | 201.2 | 59 | 138.2 | 24 | 75.2 | 11 | 12.2 |
| 93 | 199.4 | 58 | 136.4 | 23 | 73.4 | 12 | 10.4 |
| 92 | 197.6 | 57 | 134.6 | 22 | 71.6 | 13 | 8.6 |
| 91 | 195.8 | 56 | 132.8 | 21 | 69.8 | 14 | 6.8 |
| 90 | 194.0 | 55 | 131.0 | 20 | 68.0 | 15 | 5.0 |
| 89 | 192.2 | 54 | 129.2 | 19 | 66.2 | 16 | 3.2 |
| 88 | 190.4 | 53 | 127.4 | 18 | 64.4 | 17 | 1.4 |
| 87 | 188.6 | 52 | 125.6 | 17 | 62.6 | 18 | 0.4 |
| 86 | 186.8 | 51 | 123.8 | 16 | 60.8 | 19 | —2.2 |
| 85 | 185.0 | 50 | 122.0 | 15 | 59.0 | 20 | 4.0 |
| 84 | 183.2 | 49 | 120.2 | 14 | 57.2 | 21 | 5.8 |
| 83 | 181.4 | 48 | 118.4 | 13 | 55.4 | 22 | 7.6 |
| 82 | 179.6 | 47 | 116.6 | 12 | 53.6 | 23 | 9.4 |
| 81 | 177.8 | 46 | 114.8 | 11 | 51.8 | 24 | 11.2 |
| 80 | 176.0 | 45 | 113.0 | 10 | 50.0 | 25 | 13.0 |
| 79 | 174.2 | 44 | 111.2 | 9 | 48.2 | 26 | 14.8 |
| 78 | 172.4 | 43 | 109.4 | 8 | 46.4 | 27 | 16.6 |
| 77 | 170.6 | 42 | 107.6 | 7 | 44.6 | 28 | 18.4 |
| 76 | 168.8 | 41 | 105.8 | 6 | 42.8 | 29 | 20.2 |
| 75 | 167.0 | 40 | 104.0 | 5 | 41.0 | 30 | 22.0 |
| 74 | 165.2 | 39 | 102.2 | 4 | 39.2 | 31 | 23.8 |
| 73 | 163.4 | 38 | 100.4 | 3 | 37.4 | 32 | 25.6 |
| 72 | 161.6 | 37 | 98.6 | 2 | 35.6 | 33 | 27.4 |
| 71 | 159.3 | 36 | 96.8 | +1 | 33.8 | 34 | 29.2 |
| 70 | 158.0 | 35 | 95.0 | 0 | +32.0 | 35 | 31.0 |
| 69 | 156.2 | 34 | 93.2 | —1 | 30.2 | 36 | 32.8 |
| 68 | 154.4 | 33 | 91.4 | 2 | 28.4 | 37 | 34.6 |
| 67 | 152.6 | 32 | 89.6 | 3 | 26.6 | 38 | 36.4 |
| 66 | 150.8 | 31 | 87.8 | 4 | 24.8 | 39 | 38.2 |
|  |  |  |  |  |  | 40 | 40.0 |

## TABLE VIII.

### PERCENTAGE OF SUGAR IN PULP OR WASTE WATER.

### (VOLUMETRIC METHOD.)

| Polarization | Per cent. sugar | Polarization | Per cent. sugar | Polarization | Per cent. sugar | Polarization | Per cent. sugar |
|---|---|---|---|---|---|---|---|
| 0.05 | 0.014 | 1.45 | 0.415 | 2.85 | 0.817 | 4.25 | 1.218 |
| 0.10 | 0.029 | 1.50 | 0.430 | 2.90 | 0.831 | 4.30 | 1.232 |
| 0.15 | 0.043 | 1.55 | 0.444 | 2.95 | 0.845 | 4.35 | 1.246 |
| 0.20 | 0.057 | 1.60 | 0.458 | 3.00 | 0.860 | 4.40 | 1.261 |
| 0.25 | 0.072 | 1.65 | 0.473 | 3.05 | 0.874 | 4.45 | 1.275 |
| 0.30 | 0.086 | 1.70 | 0.487 | 3.10 | 0.888 | 4.50 | 1.289 |
| 0.35 | 0.100 | 1.75 | 0.501 | 3.15 | 0.903 | 4.55 | 1.304 |
| 0.40 | 0.115 | 1.80 | 0.516 | 3.20 | 0.917 | 4.60 | 1.318 |
| 0.45 | 0.129 | 1.85 | 0.530 | 3.25 | 0.931 | 4.65 | 1.332 |
| 0.50 | 0.143 | 1.90 | 0.544 | 3.30 | 0.946 | 4.70 | 1.347 |
| 0.55 | 0.158 | 1.95 | 0.559 | 3.35 | 0.960 | 4.75 | 1.361 |
| 0.60 | 0.172 | 2.00 | 0.573 | 3.40 | 0.974 | 4.80 | 1.375 |
| 0.65 | 0.186 | 2.05 | 0.587 | 3.45 | 0.989 | 4.85 | 1.390 |
| 0.70 | 0.201 | 2.10 | 0.602 | 3.50 | 1.003 | 4.90 | 1.404 |
| 0.75 | 0.215 | 2.15 | 0.616 | 3.55 | 1.017 | 4.95 | 1.418 |
| 0.80 | 0.229 | 2.20 | 0.630 | 3.60 | 1.032 | 5.00 | 1.433 |
| 0.85 | 0.244 | 2.25 | 0.645 | 3.65 | 1.046 | 5.05 | 1.447 |
| 0.90 | 0.258 | 2.30 | 0.659 | 3.70 | 1.060 | 5.10 | 1.461 |
| 0.95 | 0.272 | 2.35 | 0.673 | 3.75 | 1.074 | 5.15 | 1.476 |
| 1.00 | 0.287 | 2.40 | 0.688 | 3.80 | 1.089 | 5.20 | 1.490 |
| 1.05 | 0.301 | 2.45 | 0.702 | 3.85 | 1.103 | 5.25 | 1.504 |
| 1.10 | 0.315 | 2.50 | 0.716 | 3.90 | 1.117 | 5.30 | 1.519 |
| 1.15 | 0.330 | 2.55 | 0.731 | 3.95 | 1.132 | 5.35 | 1.533 |
| 1.20 | 0.344 | 2.60 | 0.745 | 4.00 | 1.146 | 5.40 | 1.547 |
| 1.25 | 0.358 | 2.65 | 0.759 | 4.05 | 1.160 | 5.45 | 1.562 |
| 1.30 | 0.372 | 2.70 | 0.773 | 4.10 | 1.175 | 5.50 | 1.576 |
| 1.35 | 0.387 | 2.75 | 0.788 | 4.15 | 1.189 | 5.55 | 1.590 |
| 1.40 | 0.401 | 2.80 | 0.802 | 4.20 | 1.203 | 5.60 | 1.605 |

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